RADONICS, INC.[1] (A)

Need for a Heliarc Welding[2] Fixture

Mr. Don Taylor, a designer in the microwave developmental design group at Radonics was recently asked to design a device to Heliarc weld electronic enclosures for part of a satellite transmitting system. Don's work on the project began when Bill Davis, the project engineer, handed him drawings of the electronic assembly and a one-page 8-1/2" x 11" sketch of a possible welding fixture. At this point, both the electrical and the mechanical design of the electronic assembly had already been completed.

The enclosure consisted of two small sheet metal cans connected by a metal bellows. The welded assembly was to provide an hermetically sealed environment for the enclosed electronic equipment. The company expected to produce approximately 200 of the electronic assemblies over a period of the next two or three years.

[1] Disguised name of a real company.

[2] Heliarc welding -- a type of electric arc welding using a non-consumable tungsten electrode and an inert shielding gas (detailed description given in Exhibit 11).

Prepared in the Design Division of the Department of Mechanical Engineering by Eugene J. Echterling under the direction of Karl H. Vesper, with support from the National Science Foundation.

Radonics, Inc.

Radonics, Inc., a major producer of electronic power tubes, was founded in 1934 by two radio amateurs who felt the basic weakness of radio communication lay in the power vacuum tube. They felt they could manufacture transmitting tubes capable of improving the generation and amplification of radio signals at high frequency. By 1964 annual sales volume was over $30 million. Corporate headquarters, main laboratories, and plant facilities are located on a 21 acre California site. In addition, a branch plant is located in another western state.

The company produces over 150 basic power tube types. Tube accessories, variations to meet specific customer requirements, and other electronic devices increase the total number of products to approximately 300. Typical applications are found in TV and radio broadcasting, aircraft guidance, search radar, underwater detection systems, telemetry, missile control, satellite communication systems, computer data networks, industrial radio frequency heating, and military communications. Product prices range from $5 to $25,000 per unit with weights ranging from a few ounces to more than a thousand pounds.

Total employment is about 1800. Because of the delicate and precise nature of the products much final assembly is done by hand. Strict tolerances and accurate alignment of many parts typically are required in each unit.

Special Transmitting Tube Assembly

Electrical engineers at Radonics recently completed the design of a special transmitting tube assembly to be used in a satellite system. A government contract calls for approximately 200 of the completed assemblies. About 80% of these will be for testing of prototype satellite systems. No more than 20% will be used in actual satellites.

The electronic components are housed in two rectangular cans. The large can (Exhibit 1), measuring 7.000" x 2.750" x 2.125", houses power supplies which are encapsulated in plastic resin before the container is sealed. The small can (Exhibit 2), measuring 7.000" x 0.812" x 0.823", contains a traveling wave tube, a type of amplifying tube which makes use of an interaction between an electron beam and a traveling electromagnetic wave.[1]

The two cans are connected by a metal bellows (Exhibit 3) which provides a continuous hermetic seal for electrical connections between the cans. The assembly is welded into the configuration shown in Exhibit 4. At installation the small can is turned 90° to its final position (Exhibit 5).

During production of the assembly the cans are first blanked, punched and bent. The edges of the cans are then welded. Threaded

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[1] For a detailed description of the operation of a traveling wave tube see Electronic and Radio Engineering, Fred E. Terman, McGraw-Hill Book Co., New York, 1955, pp. 679-682.

inserts, traveling wave tube support blocks, and a copper exhaust tube (to be sealed at final assembly), are next brazed in the small can (Exhibit 6). The lid for the small can is punched to receive a bellows flange and two connector mounts which are connected by brazing. Enclosure reinforcements, threaded inserts, connector adaptors, and a bellows with flange are brazed to the large can (Exhibit 7). The large can is then packaged and shipped 400 miles to the company which produces the power supplies for the assembly. This company installs the power supplies, encapsulated in a plastic resin, and returns the can to Radonics. The two connectors are then heliarc welded to the connector adaptors on the large can. Following this, the bellows flanges on the two cans are heliarc welded together. The traveling wave tube is then installed in the small can, and the necessary electrical connections are made through the bellows. Next, the lids are heliarc welded to both cans. As the final step in production, the assembly is backfilled to 10 PSIG with nitrogen through the copper tube in the small can. The copper tube is then pinched off, sealing the entire assembly.

Common Production Methods

The housing for this particular assembly was designed by the electrical engineers in the microwave developmental groups who also did the electrical design. Kovar[1] sheet, 0.020 inch thick, was chosen for the housing material. Bill Davis, head of the microwave design department, explained that Kovar was chosen because it is easier to braze than some other possible materials, such as stainless steel. He felt the number of brazing operations specified in the assembly made the brazability of the housing material a primary consideration.

Radonics engineers use heliarc welding and brazing extensively in the production of tube housings. Because of the simplicity of required tooling, furnace brazing is preferred to Heliarc welding. Bill Davis explained, however, that brazing is not always possible, "Some assemblies cannot take the heat required for brazing (1300° - 1700°F). For instance, in some of our tubes we have a cathode with a special coating which would be ruined if run through a brazing furnace. For this reason, we can only tolerate localized heating in that assembly. Also, we often use heat sinks such as large pieces of copper to protect heat sensitive areas during welding." In the drawing files, there are complete sets of drawings for 19 heliarc welding fixtures used for previous jobs. Some of these are special purpose and suitable for only one particular job; others are multipurpose and can be adapted to a variety of welding operations.

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[1] Kovar: a nickel alloy with a low thermal expansion coefficient, i.e., (3.18 x 10^{-6} in/in/°F at 0-200°F).

Assignment to Don Taylor

Don Taylor, a designer in the vacuum products division, was given the job of designing the welding fixture for this assembly. Don had received two years of training as a draftsman and equipment designer in a polytechnical school before coming to work for Radonics. During the past 14 years he has worked at Radonics as a junior draftsman, draftsman, and most recently as an equipment designer (job description given in Exhibit 8). Included in his previous designs are several heliarc welding fixtures. A mechanical engineer had worked on this design problem before being transferred to another division of the company. After being told by Bill Davis, the project leader, that he was to work on this design, Don was handed a one page 8-1/2" x 11" sketch of the mechanical engineer's idea (Exhibit 9) and drawings of the housing components and finished assembly.

Bill explained how he and the mechanical engineer went about producing the sketch he handed to Don, "About three months elapsed between the time we first began work on this project and the time when I gave Don the sketch. During this time we were working on all phases of the electronic assembly design. We were doing both electrical and mechanical design in addition to planning our tooling for production. I would estimate that about 25 man-hours were spent on the design of this welding fixture prior to production of the sketch. This time includes both my own work and that of the mechanical engineer on the project.

"Some of our first thoughts were to try building the fixture from purchased components. We thought of using a small electrically driven four wheel cart to carry the torch along a track for the linear welds. For the rotary welds, we thought of using a glass lathe to turn the parts while welding. Since a glass lathe is driven synchronously from both ends, it could give proper alignment of the parts during the rotary welding operations. After considering possible combinations of purchased items, however, we decided to design one machine which would do all the necessary welds. We didn't want several machines sitting around the shop taking up space if one machine could do the job. This sketch, as you can see, was only a rough schematic. I didn't expect Don to proceed with only this one idea. I expected him to try thinking of different ideas and to sketch other possible configurations. If he could convince us that any of his ideas were better, we were certainly not going to insist upon sticking to the sketch. He was aware of our early thinking on the fixture design, however, and knew what kind of ideas we had considered and rejected."

Don's job was to design a welding fixture to perform all heliarc welding operations on the assembly. This included welding the corner seams on both can sizes, welding two electrical connectors to the connector adaptors on the large can, welding the bellows flanges together, and welding the lids on both cans. He was told that the expected production quantities were less than 200 cans and that as a result he was not to worry about cutting a few seconds off loading time for the welding fixture, as would be the case if this were to be a very high production item. He was also told that the original estimate of the cost of this fixture was about $2,000. Bill Davis explained that this estimate was submitted by a

tool engineer while the machine was still in the conceptual stage. He said the estimate was made by comparing this machine concept with similar machines which were made in the past, and whose costs were known. The government agency sponsoring this project was to pay for any costs of special tooling needed for the production of the electronic assembly provided it was not of general purpose nature.

Heliarc Welding

Radonics has several heliarc welding power supplies and a variety of welding torches (Exhibit 10), all of which have been used in conjunction with previous welding fixtures. A general description of heliarc welding is given in Exhibit 11. An engineer in the sales department of the Linde Company[1] gave more specific data relating to the welding of 0.020" thick Kovar. He said that no filler metal will be needed for material this thin. Optimum arc length will be somewhere between 1/8 x 3/16", depending upon the speed of weld. Deviations from the optimum arc length should be no more than ± 0.010". The speed of torch travel can be anywhere between 12-100 inches per minute depending upon desired production rates. For the types of weld to be used in this design, the engineer at Linde Company did not foresee any particular difficulty arising from shrinkage stresses occurring during the welding operation. To assure proper weld penetration he felt it would be desirable to provide an inert gas atmosphere in back of the pieces to be welded (nitrogen is commonly used for this purpose). He also mentioned that such welds could possibly be performed using very simple clamping fixtures and hand operation of the torch if the intended production quantities were small.

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[1] Linde Company, a division of Union Carbide, produces the heliarc welding equipment used by Radonics, Inc.

ECL-27

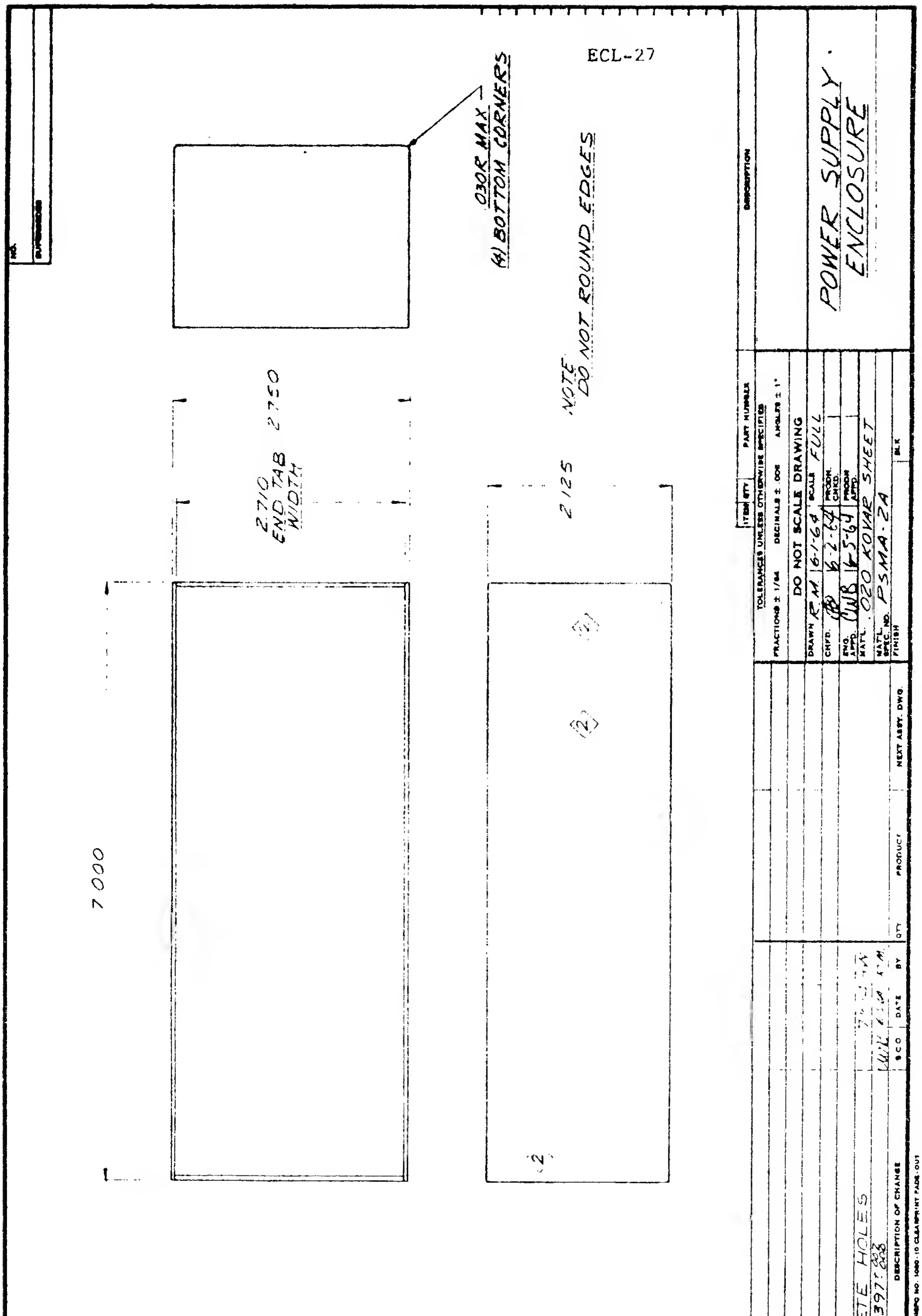

Exhibit 1: Large Can for Electronic Housing.

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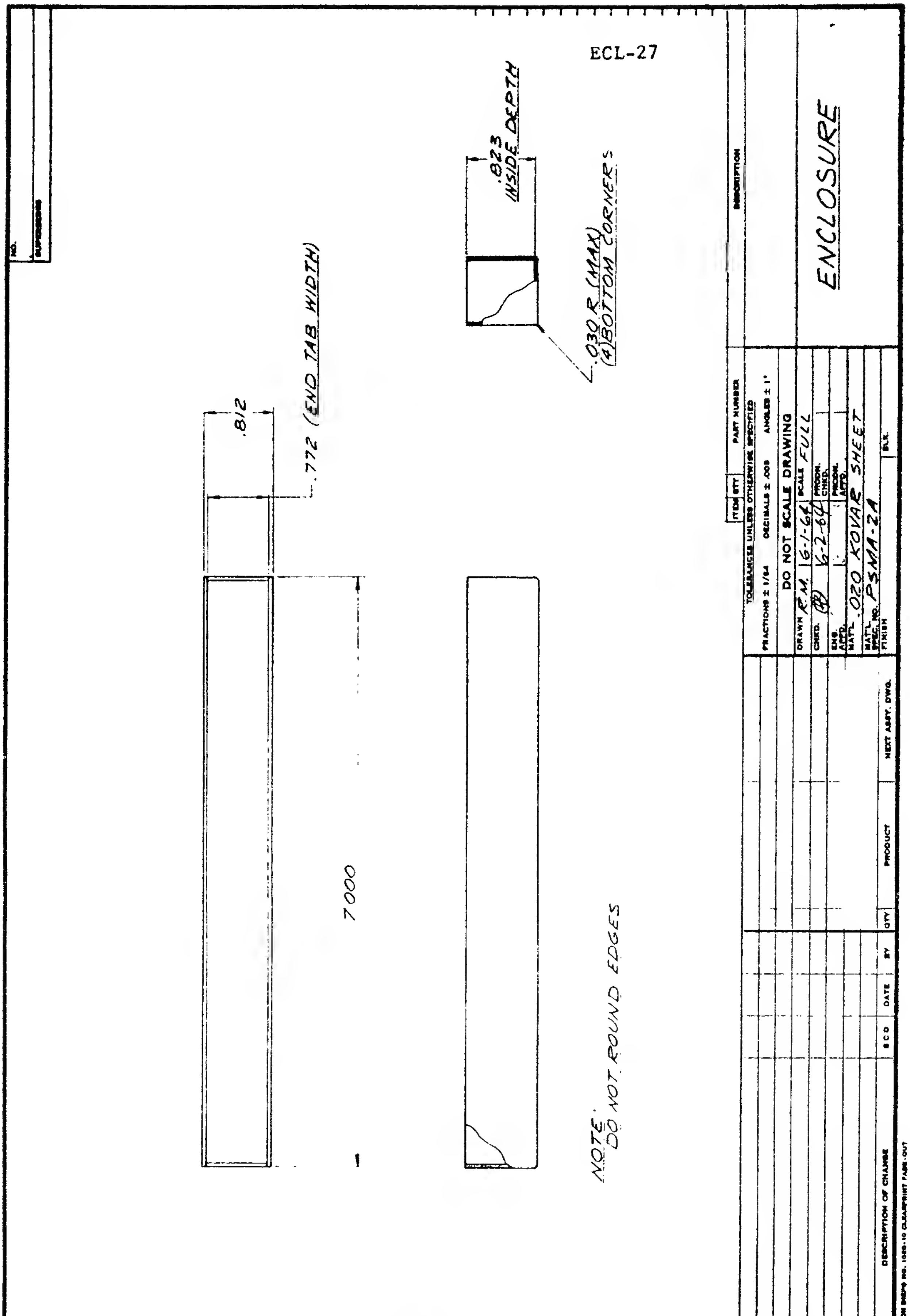


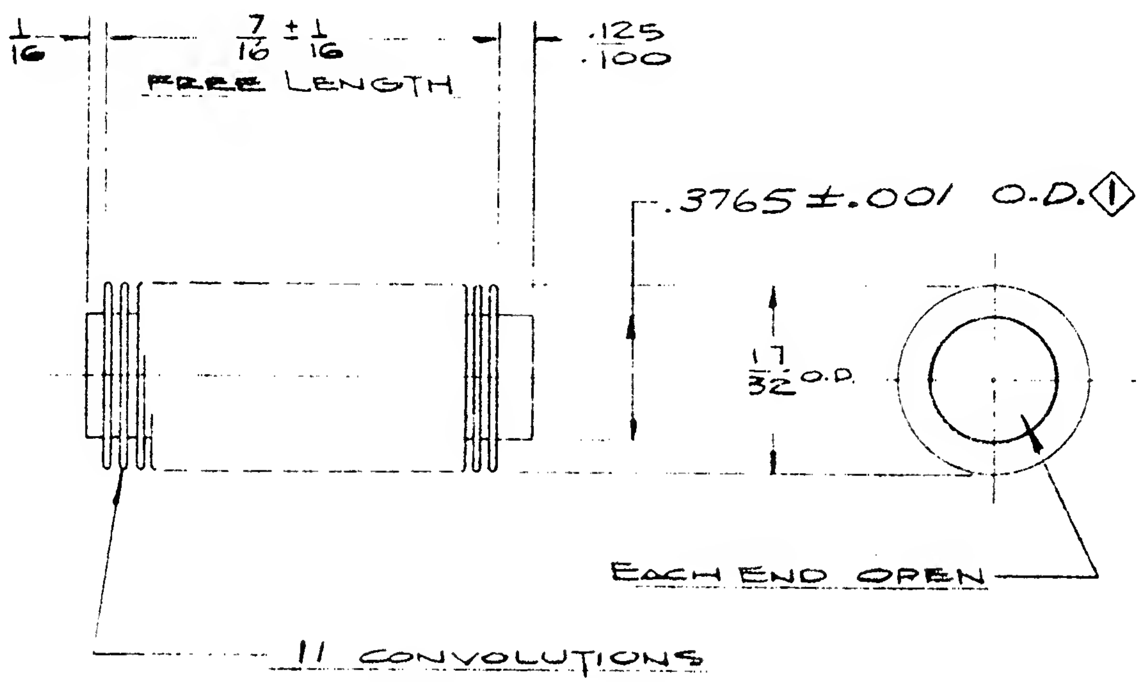
Exhibit 2: Small Can for Electronic Housing.

QTY	PRODUCT	NEXT ASSY DWG	NO.	DESCRIPTION OF CHANGE	ECO	DATE	BY
			1	WAS -375+000-002	CE	1-6-63	B

SUPSDS.

ECL-27

Exhibit 3: Metal Bellows for Connecting the two Cans.



MAT'L: KOVAR BELLOWS 17/32 O.D. - 3/8 O.D. AT ROOT x .00475 TO .00525 WALL, 11 CONVOLUTIONS

ITEM	QTY	PART NUMBER	DESCRIPTION

TOLERANCES UNLESS OTHERWISE SPECIFIED

FRACTIONS ± 1/64 DECIMALS ± .005 ANGLES ± 1°

DO NOT SCALE DRAWING

DRAWN R.M.	10-14-63	SCALE 2/1	
CHKD. B	1-6-64	PRODN. CHKD.	
ENG. APPD.		PRODN. APPD.	
MAT'L NOTED			
MAT'L SPEC. NO.			
FINISH		BLK.	

BELLOWS

PRINTED ON DIEPO NO. 1020-10 CLEARPRINT FADE-OUT

Exhibit 4: Welded Configuration of Cans and Bellows.

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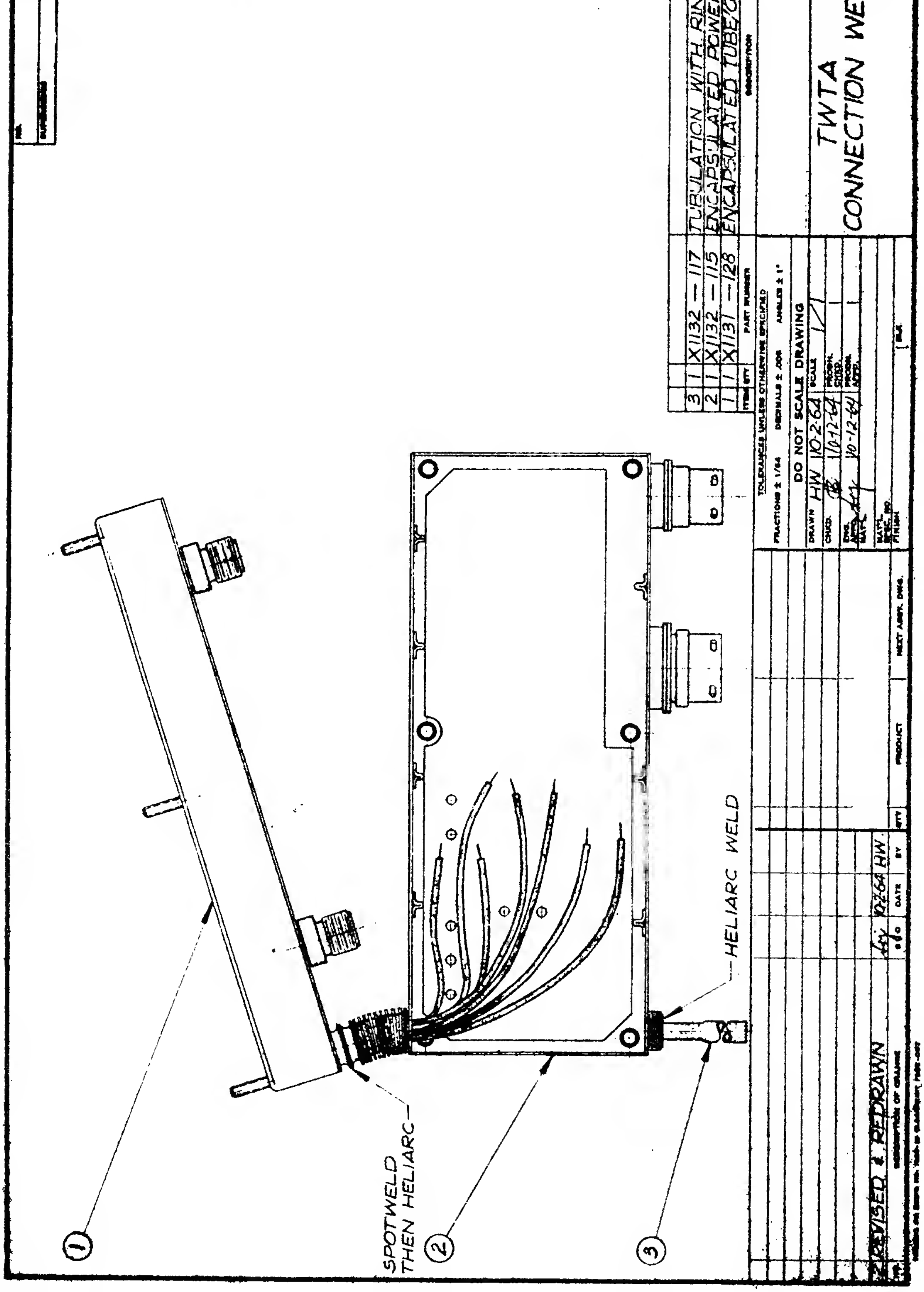

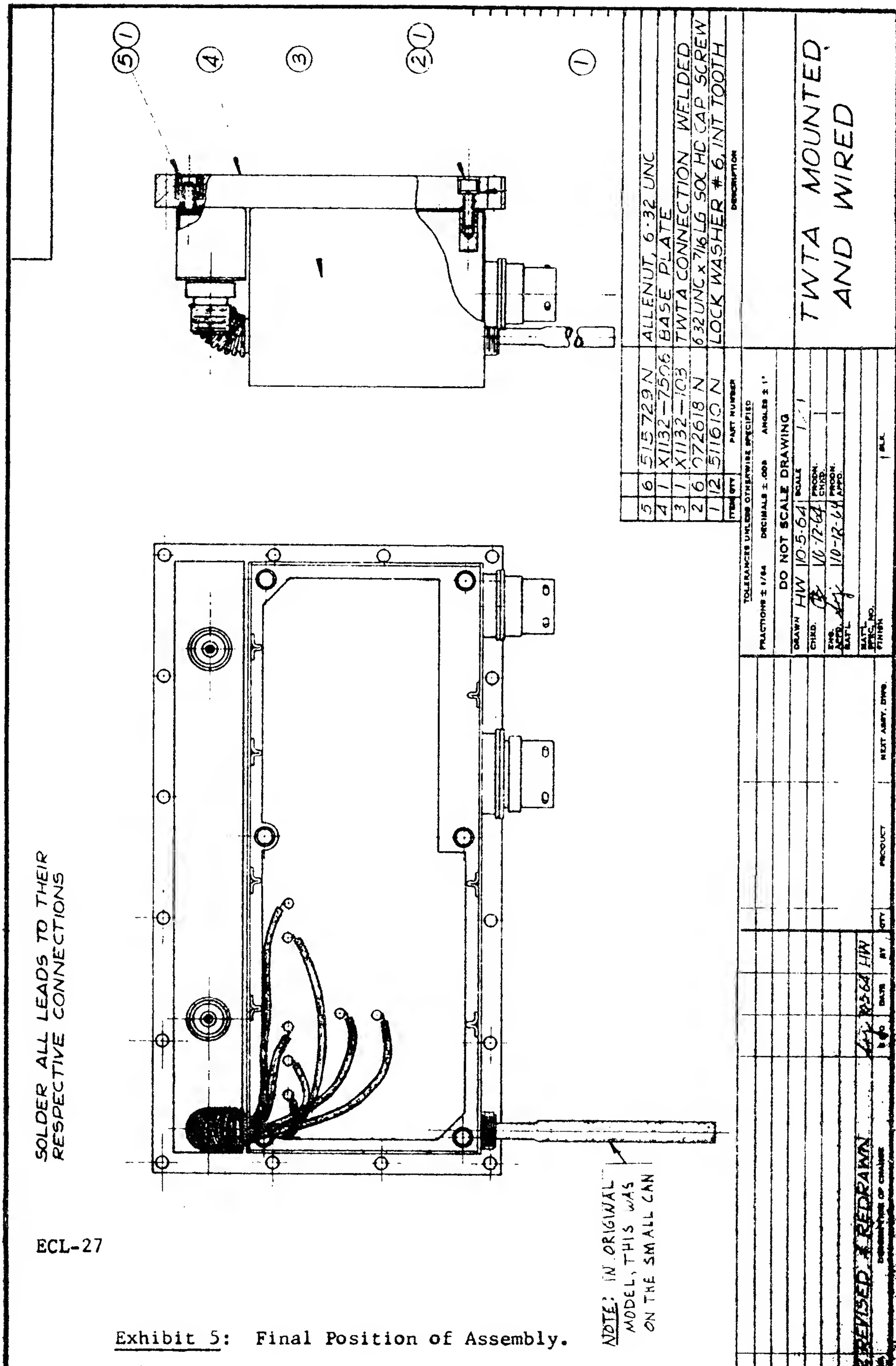

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Exhibit 5: Final Position of Assembly.

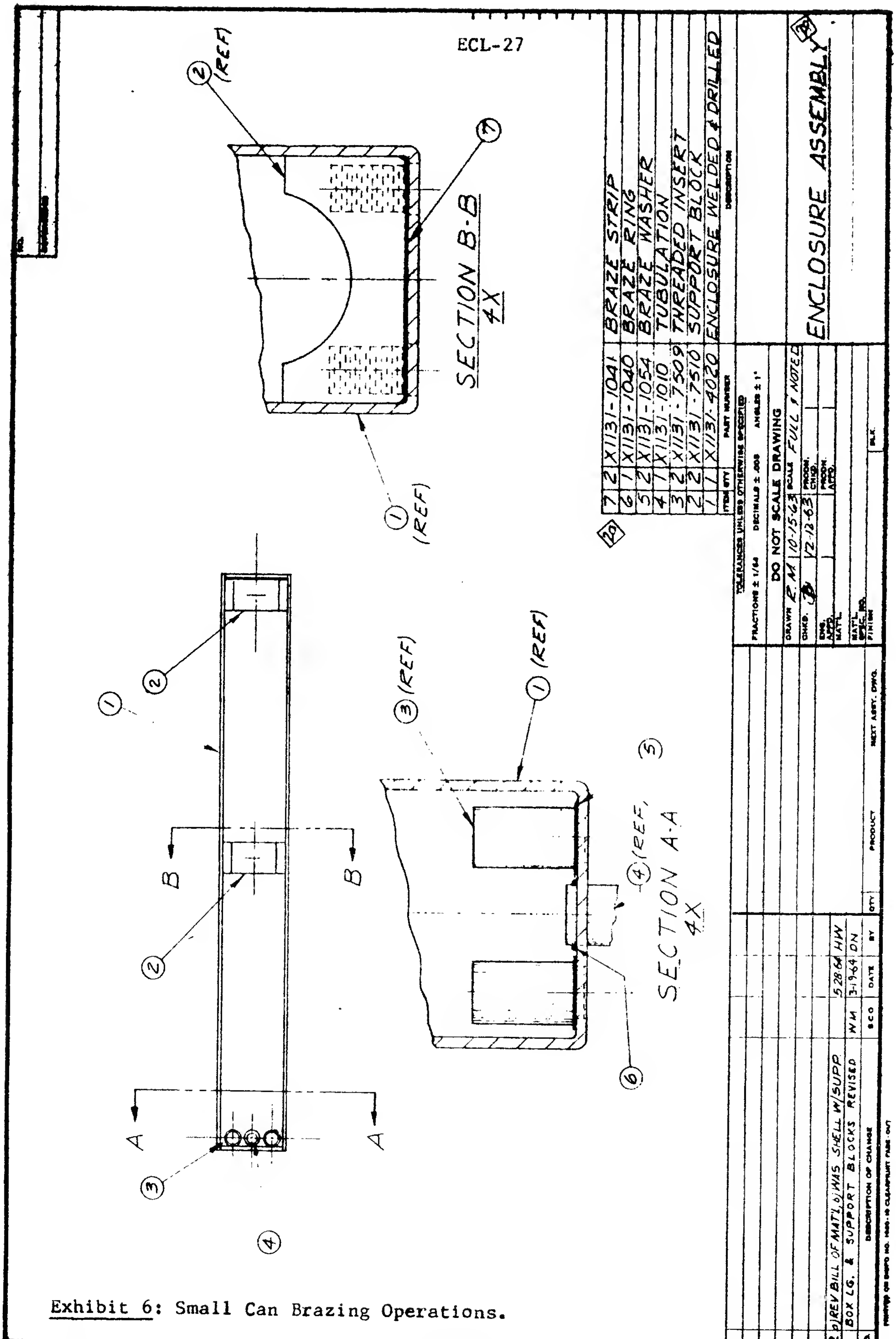


Exhibit 6: Small Can Brazing Operations.

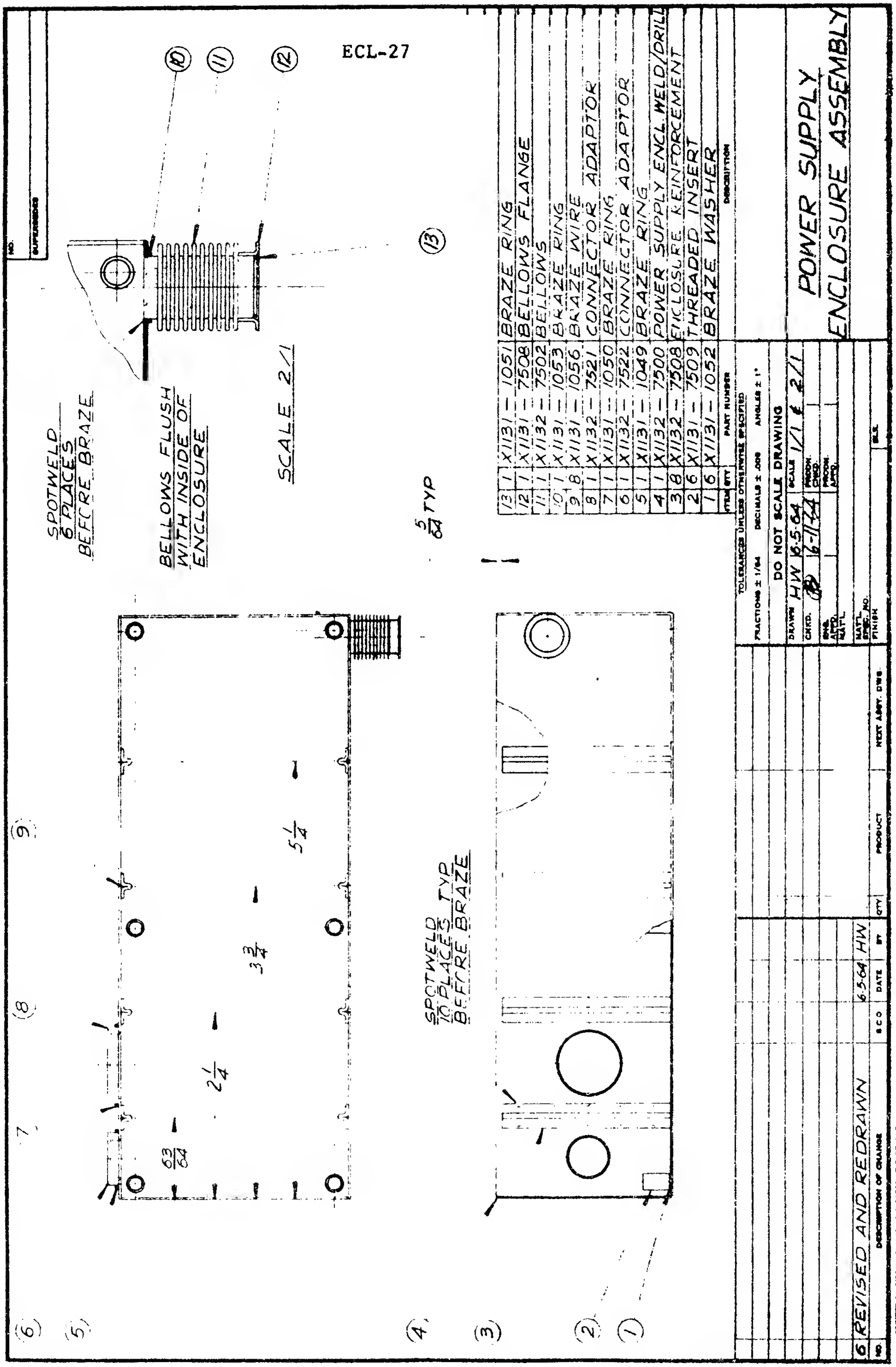


Exhibit 7: Large Can Brazing Operations.

EXHIBIT 8

RADONICS, INC.

Job Description

JOB TITLE: DESIGNER

General Purpose Under guidance of engineers, provides mechanical and/or electrical designs of equipment, components, or tubes. Designs and/or executes layouts from concepts and data received from engineers

Major Duties

1. Perform difficult design assignments and plans and advises draftsmen on complex drawings, applies advanced drafting techniques and knowledge of practical mechanical, electrical or fabrication problems.

2. Prepares working sketches and complex layouts from which draftsmen prepared final design drawings; these are based on information provided by engineers.

3. Consults catalogs or other sources to determine choice of components to incorporate in the design, if not already specified.

4. May confer with those in the shop or plant on particular characteristics of existing equipment, components, or tubes.

5. May consult project originators to establish firm specifications, combines mechanical and electrical criteria and incorporates them in the design and finished drawings.

6. Directs the work of other subordinate draftsmen in the completion of working drawings to assure accuracy and consistency, gives technical guidance as required.

7. Maintains records and progress reports on extended projects.

8. Checks all drawings for completeness accuracy, suitability of tolerances, adaptability to manufacturing.

9. May calculate less complex mechanical or electrical engineering problems.

10. May assist in making manhour estimates.

EXHIBIT 8 (con't.)

TECH. FACTOR ANALYSIS

636 - DESIGNER

KNOWLEDGE AND SKILL REQUIREMENTS

Requires thorough knowledge in all matters of standards, practices (in design and in the shop), equipment and material specifications, and governmental codes. High school or junior college training or equivalent plus a minimum of six years of experience is usually necessary to meet the minimum qualifications of this job.

INDEPENDENT ACTION REQUIREMENTS

High degree of delegated independent decision-making related to the choice of components and general layout of most complex design requirements. Normally, specifications are outlined by engineers, and the incumbent plans the design to meet these overall specifications.

ACCURACY - EFFECTS OF ERRORS

Errors in choice of components, tolerances, dimensions, or general layout in terms of adaptability to fabrication may lead to project delay, or wasteful use of equipment or materials To correct errors would require a new designing and drafting project.

RELATIONSHIPS REQUIRED

Frequent contact with shop personnel and engineers to exchange information on design details. In addition, the incumbent normally has responsibility for giving functional direction to one or more other draftsmen in the completion of all drawings.

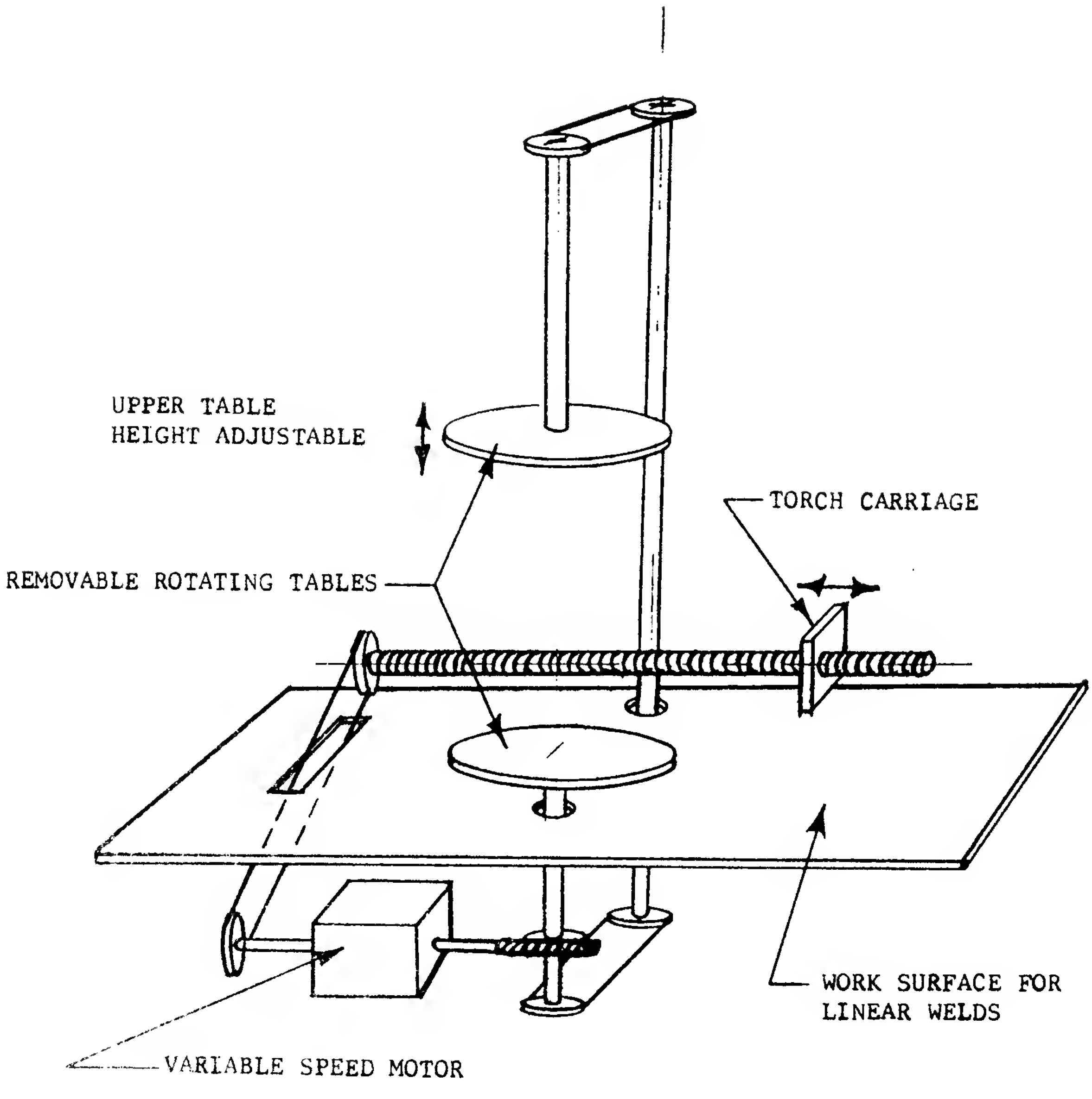
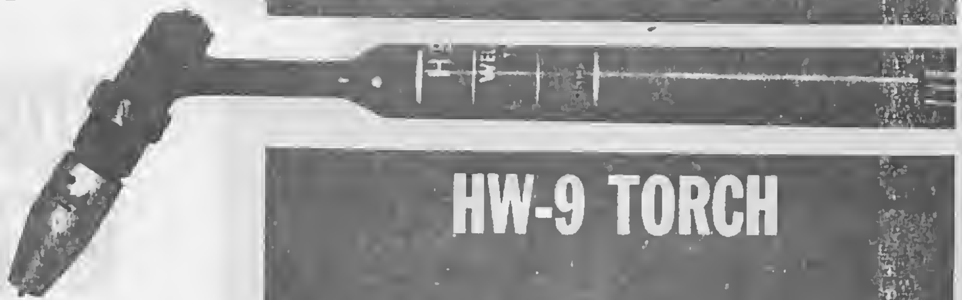


Exhibit 9:

Proposed Mechanical Schematic
for a Heliarc Welding Fixture to be
Designed by Don Taylor.
(Drawn by Bill Davis)

Exhibit 10: Heliarc Welding Torches

MIDGET TORCHES



HW-9 TORCH

HW-9 PENCIL TORCH

110 amps

for welding thin-gage materials in confined areas

The HW-9 Torch and HW-9 Pencil Torch are small, lightweight, and specifically designed for welding thin-gage materials. Both torches are particularly suited for working in confined areas.

Narrow Head and Handle—Small diameter—only ¾ in.—permits welding in confined areas.

Optimum Gas Flow—Positive gas distribution pattern for minimum gas flow.

Screw-On Connections—Simple, quick assembly and replacement of cable and hoses.

Sturdy Construction—Rugged materials and simple design assure long, trouble-free operation.

HW-9 TORCH

Selection of Gas Pattern—New "Gas Lens" accessory gives even better shielding and longer torch-to-work distances. A variety of interchangeable ceramic cups permits the formation of the most appropriate gas pattern. Shielding can be adjusted to the requirements of the joint.

Two Working Angles—Collet body and torch cap are interchangeable, providing two working angles for the torch head: either 60 or 120 degrees from cup to handle.

Supplied with Two Caps—Short cap is for 3-in. electrode used for confined spaces; long cap adapts torch for use with 7-in. electrode.

HW-9 PENCIL TORCH

All parts are the same as those in the HW-9 Torch except the body. The Pencil Torch body is of bronze, enclosed in a high-impact plastic tube.

In-Line Construction—Easy access to difficult weld locations where a tilted head would be impractical.

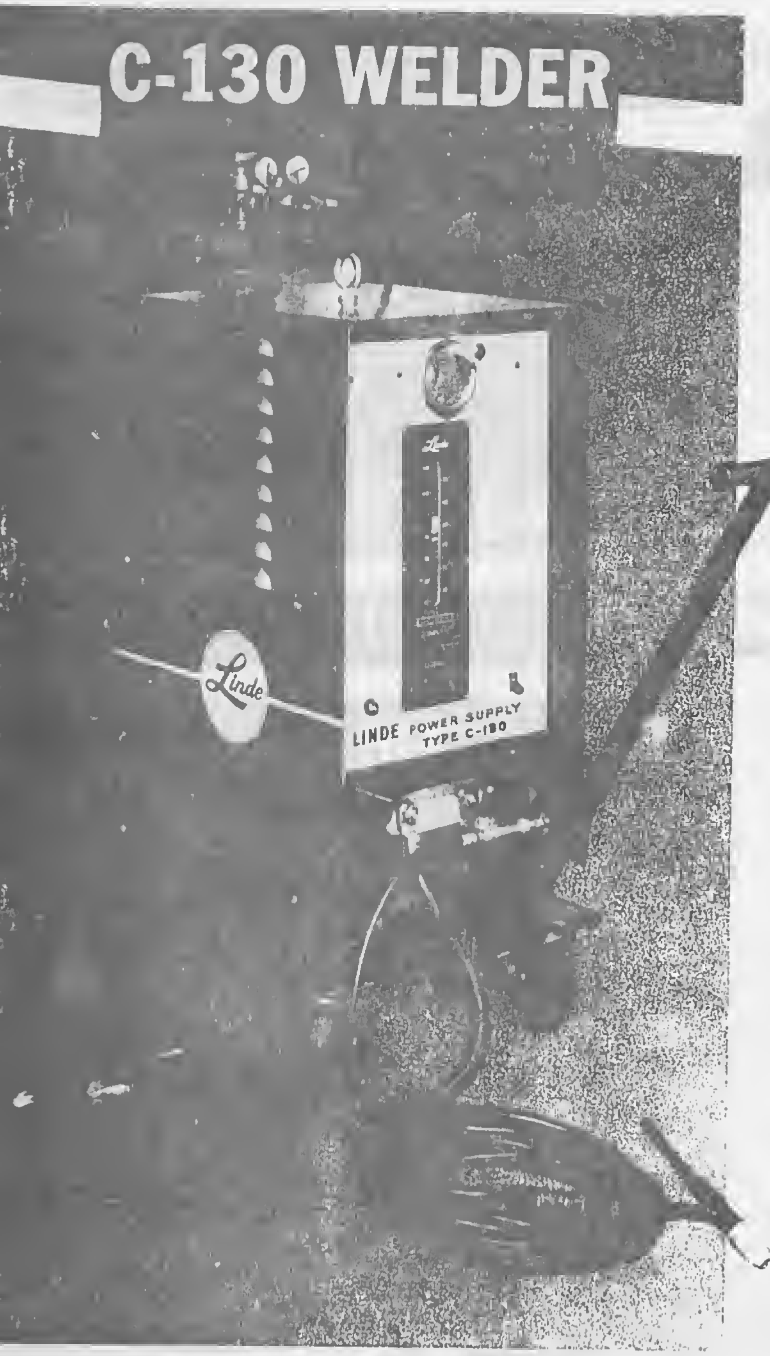
SPECIFICATIONS

	HW-9 Torch	HW-9 Pencil Torch
Capacity:	110 amps—continuous duty—a.c. or d.c.	110 amps—continuous duty—a.c. or d.c.
Weight:	3 ounces (less cable and hose)	5 ounces (less cable and hose)
Over-all Torch Length:	8¾ in.	7⅛ in.
Handle Diameter:	¾ in.	¾ in.
Length of Torch Head:	3⅛ in. (short cap) 7⅛ in. (long cap)	
Head Diameter:	¾ in.	
Electrode Sizes:	.020 to ¹⁄₁₆ in.	.020 to ¹⁄₁₆ in.

STANDARD ACCESSORIES
Ceramic Cups • High-Impact Cups, Regular and Long • Collets • Gas Regulating Equipment

"GAS LENS" ACCESSORIES
High-Impact Cups • Ceramic Cups • Collets • "Gas Lens"/Collet Body Units • Collet Body Insulator

OPTIONAL ACCESSORIES
Torch-Saver Flow Switch • V-30 Shutoff Valve • Asbestos Hose Sheath



PORTABLE WELDER ...rolls to the job

HELIARC C-130 combines the speed, quality, and versatility of HELIARC welding with the portability and simplicity of stick electrode welding. Now it's possible to roll a complete HELIARC welding unit to the job. Ideal for:

- Thin-wall pipe and duct work
- Field erection welding
- General plant maintenance
- Light production welding
- Welds stainless, low-alloy and carbon steels up to $\frac{3}{8}$ in. thick in one pass

You get everything needed to start welding:

LINDE C-130 constant-current power supply
LINDE Model TR-1 four-wheel tow-cart
HELIARC HW-17 torch, complete with argon shut-off valve and 25-ft. service leads
LINDE R-509 argon regulator
25 ft. of welding cable with clamp
Bus bar and connection hardware
6 High-impact cups
3 Collets
3 Collet bodies

Put in an electrode, connect an argon gas cylinder, roll it to the job and go to work.

Mobility—Portable cart is small, lightweight, highly maneuverable. Large wheels, low center of gravity, and heavy-duty tow-handle make it easy to pull over obstructions and up steep grades without tipping. Base of the cart extends beyond the equipment on all sides. Entire unit, less the cylinder, weighs only 275 pounds. The 25-ft. service leads make it easy to move about and work freely away from the cart. Auxiliary shut-off valve on the HW-17 torch makes returning to the cart for adjustments unnecessary. Lifting eye on top of power supply for hoisting.

Adaptability—"Q," "S" or "T" argon cylinders, contain—80, 150, or 330 cu. ft. of gas, will all mount securely on the cart. Select the size tank needed for the job. A maximum of six hours of welding time is available when a "Q" tank is used.

Power Supply—The LINDE C-130 Power Supply requires single-phase, 230-volt, 60-cycle a.c. power. It has an output of 130 amps, d.c., with a 60% duty cycle and 150 amps with a 40% cycle. Unusually good HELIARC welding characteristics make the arc easy to strike and the unit exceptionally quiet and smooth in operation. Controls are conveniently mounted on the front panel and include a switch for energizing torch. A pilot light indicates when the unit is energized. Welding current is adjusted from 25 to 150 amps by simply turning a vernier hand wheel. Visual indication of the current setting is shown on a clearly marked scale.

HELIARC *HW-17 Torch*—The HW-17 is an air-cooled, manual welding torch. It operates at 130 amps, d.c., continuous duty —the maximum capacity can be increased if operated on reduced and intermittent duty cycles.

R-509 Regulator—A precision regulator-flowmeter which delivers the correct flow rate of shielding gas for HELIARC welding, controllable up to 40 cubic feet per hour.

HANDLING THE TORCH

A. Starting an Arc

There is nothing difficult or technical about starting an arc in the proper manner. We recommend the particular procedure outlined briefly below, to ensure maximum protection of the workpiece from the atmosphere at the start of welding operations.

In a.c. welding, the electrode does not have to touch the workpiece to start the arc. The superimposed high-frequency current jumps the gap between the welding electrode and the work thus establishing a path for the welding current to follow. To strike an arc, first turn on the power supply and hold the torch in a horizontal position about 2 inches above the workpiece or starting block, as shown in Figure 18 below. Then quickly swing the end of the torch down toward the workpiece, so that the end of the electrode is about 1/8 inch above the plate. The arc will then strike. This downward motion should be made rapidly to provide the maximum amount of gas protection to the weld zone. Figure 19 shows the torch position at the time the arc strikes.

In d.c. welding, the same motion is used for striking an arc. However, in this case, the electrode must touch the workpiece in order for the arc to start. As soon as the arc is struck, withdraw the electrode approximately 1/8-inch above the workpiece to avoid contaminating the electrode in the molten puddle. High frequency is sometimes used to start a d.c. arc. This eliminates the need for touching the workpiece. The high frequency is automatically turned off by means of a current relay when the arc is started.

The arc can be struck on the workpiece itself or on a heavy piece of copper or scrap steel, and then carried to the starting point of the weld. Do not use a carbon block for starting the arc, as the electrode becomes contaminated causing the arc to wander (see Section B below). When starting to weld with a hot electrode, the action must be very rapid as the arc tends to strike before the torch is in proper welding position.

To stop an arc, merely snap the electrode quickly back up to the horizontal position. This motion must be made rapidly so the arc will not mar or damage the weld surface or workpiece.

B. Arc Wandering

With the torch held stationary, the points at which an arc leaves the electrode and impinges upon the workpiece may often shift and waver without apparent reason. This is known as "arc wandering," and is generally attributed to one of the following causes: (1) low electrode current density, (2) carbon contamination of the electrode, (3) magnetic effects, and (4) air drafts. The first two causes are distinguished by a very rapid movement of the arc from side to side, generally resulting in a zig-zag weld pattern. The third cause, magnetic effects, usually displace the arc to one side or the other along the entire length of the weld. The fourth causes varying amounts of arc wandering, depending upon the amount of air draft present.

When current density of the electrode is at a sufficiently high level (see torch instruction booklet for recommended amperages for various diameter electrodes), the entire end of the electrode will be in a molten state and completely covered by the arc. When too low a current density is used, only a small area of the electrode becomes molten resulting in an unstable arc which has poor directional characteristics and is difficult for the operator to control. Too high a current density results in excessive melting of the end of the electrode.

Although we clearly advise against striking an arc with a carbon pencil or on a carbon block, it is quite often done and is a primary cause of arc wandering. When the carbon touches the molten tungsten, tungsten carbide is formed. This has a lower melting point than pure tungsten, and forms a large

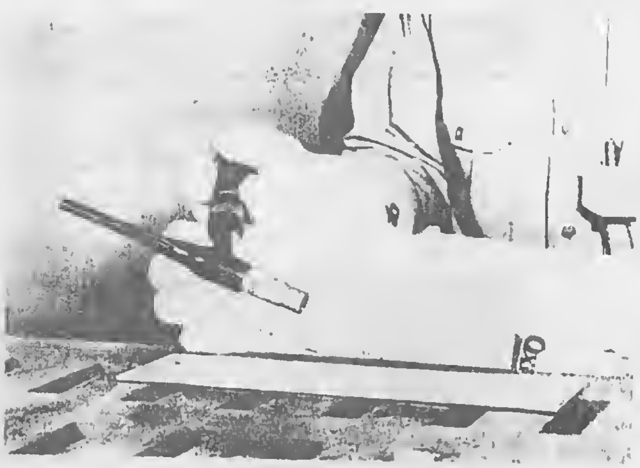


FIG. 18 – Torch Position for the Starting Swing

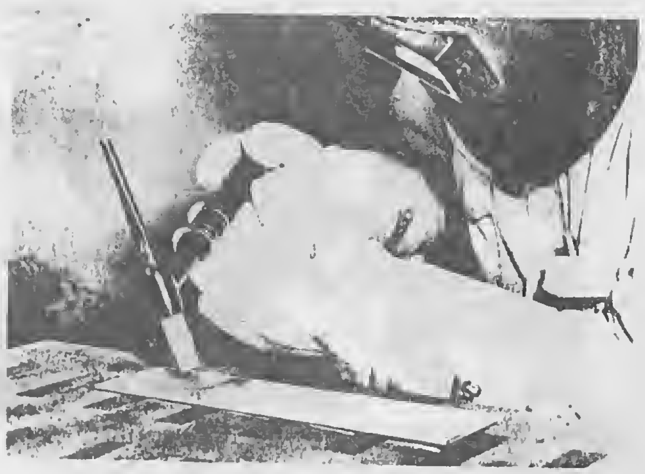


FIG. 19 – End of Swing to Draw an Arc

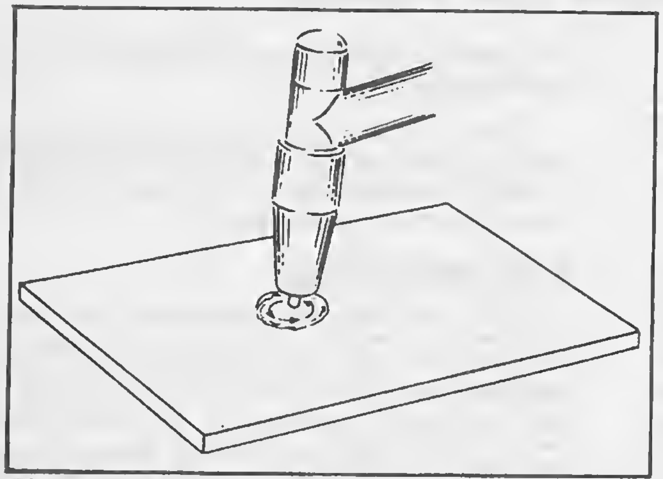


FIG. 20 – Forming a Molten Puddle with a HELIARC Torch

molten ball on the end of the electrode. This in effect reduces the current density at the electrode end, and arc wandering then occurs. The electrode can also be contaminated by touching it to the work piece or filler rod. When electrode contamination occurs in any form, it is best to clean the electrode by grinding, break off the contaminated end, or use a new electrode.

Magnetic effects are not generally encountered, and are too complex to be discussed fully. The most common magnetic action on an arc, however, results from the magnetic field set up by the current flowing through the workpiece. This magnetic field may tend to attract or repel (depending on its polarity) the arc from the normal path. One method of remedying this condition is to alter the position of the ground connection on the workpiece until the effects are no longer noticed. Often the hold-down jaws of the welding fixture may have to be changed to a non-magnetic material such as bronze, copper or stainless steel.

C. Making a Butt Weld

After the arc has been struck, hold the torch at about a 75 degree angle to the surface of the workpiece. The starting point of the work is first preheated by moving the torch in small circles (see Figure 20) until a molten puddle is formed. The end of the electrode should be held approximately 1/8-inch above the workpiece. When the puddle becomes bright and fluid, move the torch slowly and steadily along the joint at a speed that will produce a bead of uniform width. No oscillating or other movement of the torch except for the steady forward motion is required.

FIG. 21 – Position of Torch and Rod for Making a Butt Weld

When filler metal is required to provide adequate reinforcement, the welding rod is held at about 15 degrees to the work and about one inch away from the starting point. First preheat the starting point and develop the puddle as described above. When the

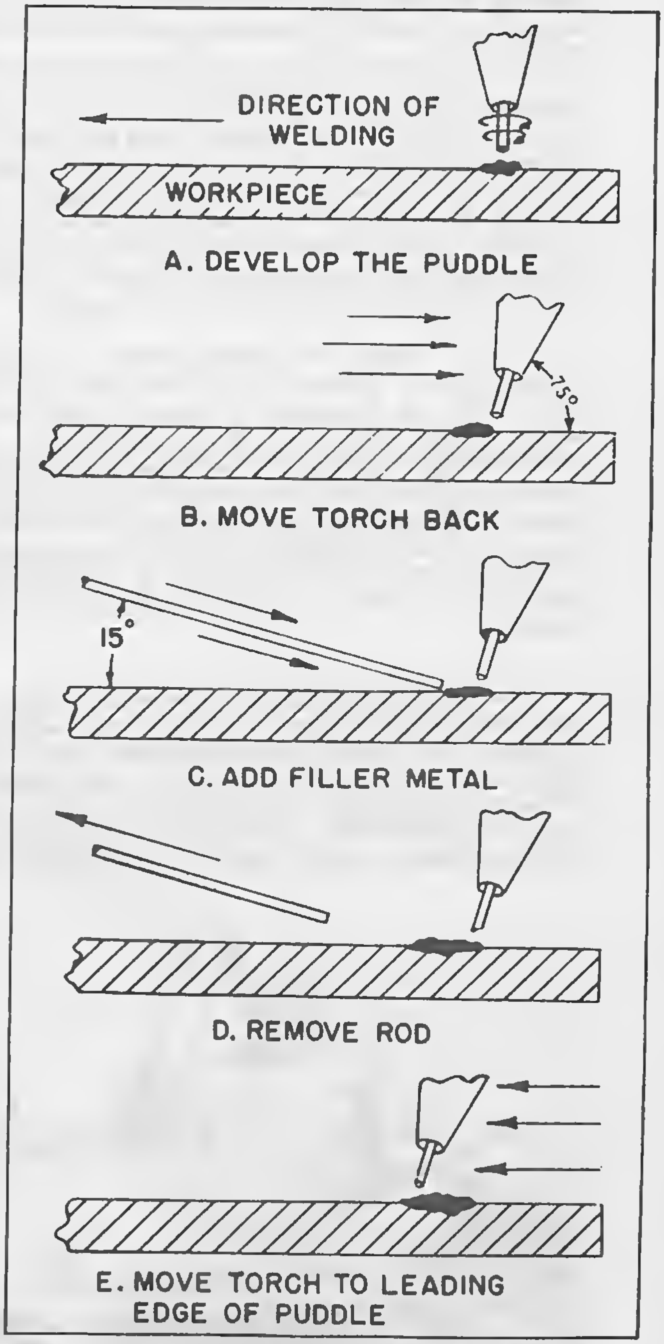


FIG. 22 – Addition of Filler Metal (Flat Position)

Exhibit 11 (cont.): Heliarc Welding.

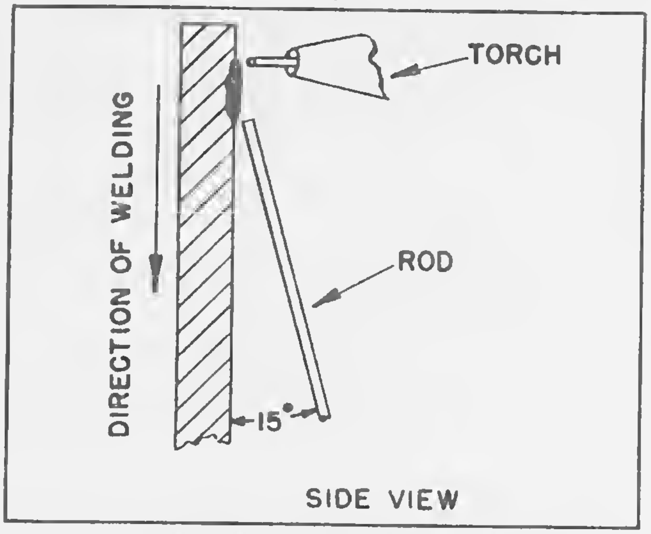


FIG. 23 – Addition of Filler Metal (Vertical Position)

puddle becomes bright and fluid, move the arc to the rear of the puddle and add filler metal by quickly touching the rod to the leading edge of the puddle. Remove the rod and bring the arc back up to the leading edge of the puddle. As soon as the puddle is again bright, repeat the same steps. This sequence is continued for the entire length of the seam. Figure 22 illustrates the steps graphically. The rate of forward speed and amount of filler metal added will depend on the desired width and height of the bead.

For making butt joints on a vertical surface, the torch is held perpendicular to the work. The weld is usually made from top to bottom. When filler rod is used, it is added from the bottom or leading edge of the puddle in the same manner as described above. Figure 23 above shows correct positioning of the rod and torch relative to the workpiece.

D. Making a Lap Weld

A lap weld or joint is started by first developing a puddle on the bottom sheet. When the puddle becomes bright and fluid, shorten the arc to about 1/16-inch. Oscillate the torch directly over the joint until the sheets are firmly joined. Once the weld is started, the oscillating movement is no

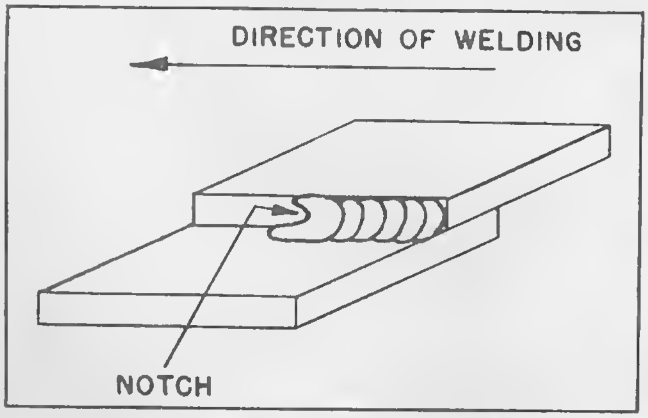


FIG. 24 – Lap Welding Technique

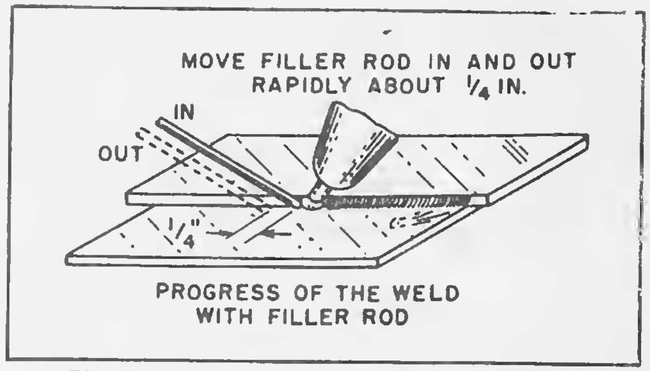


FIG. 25 – Progress of a Lap Weld with Filler Rod

longer necessary. Merely move the torch along the seam holding the end of the electrode just above the edge of the top sheet.

In lap welding, the puddle developed will be boomerang- or vee-shaped. The center of the puddle is called the "notch," and the speed at which this notch travels will determine how fast the torch can be moved ahead. Care must be taken that this notch (see Figure 24) is completely filled in for the entire length of the seam. Otherwise, it is impossible to get 100 per cent fusion and good penetration.

When filler metal is used, faster welding speeds are possible as the rod helps fill up the notch. Be sure to get complete fusion, however, and not merely lay in bits of filler rod on cold, unfused base metal. The rod should be alternately dipped into the puddle and withdrawn 1/4-inch or so, as illustrated in Figure 25. By carefully controlling the melting rate of the top edge, and by adding just the right amount of filler metal where needed, a good uniform bead of proper proportions can be obtained.

E. Making a Corner or Edge Joint

This is the easiest type of HELIARC weld to make. Develop a puddle at the starting point, and then move the torch straight along the joint. Regulate travel speed to produce a uniform looking bead. Too slow a welding speed will cause molten metal to roll off the edge. Irregular or too high speeds will produce a rough, uneven surface. No filler metal is required. The position of the welding torch is shown in Figure 26.

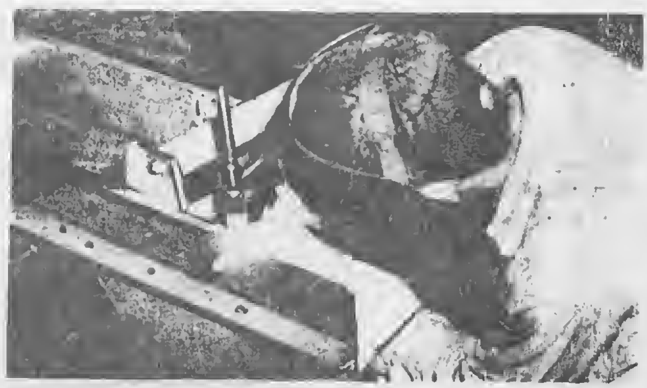


FIG. 26 – Welding an Edge Joint

Don explained how this affected further development of the machine, "Because of the disagreement over cost allotment, all authorization for further work on this machine was stopped. As a result, noe of my improvements have been completed. The project engineer contended that if the machine was de-bugged and operating properly, it would be regarded as general purpose equipment and the government would not bear its cost. If it must be scrapped after completion of the project, the government will probably bear the cost.

"Presently the only work being done on the machine is the welding of the bellows. All other welds are being done by fully manufal welding."

RADONICS, INC. (B)

Design of a Heliarc Welding Fixture[1]

When Don began working on the design of a heliarc welding fixture to weld some special electronic housings, he found that most of the design considerations had already been set by engineers who worked on the project before him. He made the following comments about the effect this had on his work, "When I received the work order for this project, I recognized that several important deoisions affecting the design had already been reached. These were:

1. The job to be done was fixed, as far as I was concerned (that is, they had definitely decided to weld the enclosures).
2. The decision to build a special machine to do this welding had been made.
3. Several basic features of the machine had already been decided upon. These included two synchronously driven adjustable vertical spindles for the rotary welds, a screw-driven carriage to perform the linear welds, and a common variable speed drive.

"This was what I started with, and even though I felt that the design of the electronic assembly, which required such expensive tooling, was perhaps arbitrary and subject to improvement, I had no alternative but to proceed as requested.

Design Procedure

"After looking over the assembly to be welded and the proposed welding fixture schematic, I noticed that the only operation requiring the upper spindle was the welding of the bellows. The connectors were merely laid on their mating holes in the can with only the lower spindle, which held the can, rotating during the weld. A change in the enclosure design to eliminate the need for the welded bellows would have greatly simplified the machine by eliminating the need for an upper spindle. Since this had already been decided, however, I went ahead with a design based on the sketch I was given.

[1] Based on a design problem presented in RADONICS,INC. (A); Need for a Heliarc Welding Fixture.

"The original sketch showed the column at the back of the work table. To shorten by several inches the overhand of the upper spindle, I moved it to the left side. This also required that I move the linear traverse mechanism about a foot to the left. I then asked myself how big the work table of the machine should be. To answer this question, I determined the largest radius about a point of rotation on the large can and took a circle of that radius as the minimum clearance required on the table work area. For operator convenience, I chose a table height of 32 inches.

"I decided to make both upper and lower spindles the same, so chucks would be interchangeable. To avoid worktable interference, I did not let the top of the lower spindle protrude above the table. Instead, the chuck was slipped over the spindle through a hole in the worktable. I wanted the upper spindle to be easily removable when only linear welding was being done. The upper spindle also had to be adjustable vertically. For fine adjustments, I designed a screw driven carriage which attached to the top end on the spindle. The elevating screw, with an attached hand knob, was mounted alongside the spindle (Exhibit B-1). For gross adjustments, the whole upper spindle head assembly could be moved up or down on the spindle supporting column. Both upper and lower spindle mounts were attached to the spindle column, which extended through the table top. On the upper column mount, I made the bearing mount and sprocket assembly movable to provide for chain take-up (Exhibit B-1). Ball bearings were used throughout the spindle assemblies.

"The next step was to get the correct welding speed for both circular and linear welding. This involved motor and motor speed controller selection. Then I had to choose the gear ratios for all the driven assemblies, consisting of combinations of gears, chains, and sprockets. I chose a 1/15 horsepower, 115 volt D.C. gearmotor with a voltage speed control unit. The controller permitted speed regulation in either direction. I added a solenoid operated clutch between the gearmotor and the drive mechanism to leave the spindle free to turn by hand while setting up for a weld.

"For the torch carriage, I designed a half-nut clamping device (Exhibit B-2) which either locked the carriage solidly on two horizontal 5/8" diameter guide rods (during rotary welds) or engaged the carriage with the driving screw (during linear welds). When I was designing the clamping assembly I found that I could not get the ball bushings I wanted in 5/8" diameter. I was therefore faced with the choice of either using 1/2" diameter guide rods,which I thought were too small, or 3/4" diameter rods which made the clamping assembly unduly large. Rather than increase the size of the clamping assembly, I chose the 1/2" rods. A hand knob atop the clamping assembly could be turned to engage or disengage the torch carriage (Exhibit B-3). Turned all the way clockwise, the carriage engaged the drive screw; turned all the way counterclockwise the carriage locked on the support rods."

Protruding from the torch carriage was an adjustable ball and socket clamp (Exhibit B-4) which held the welding torch. Don explained the reasons for using this device, "We often borrow designs of certain details from other machines. An example is the ball and socket clamp used in this machine. The company has in its files drawings for 19 previously designed heliarc welding machines. Whenever possible, we take details directly from these machines and re-use them."

Don also commented on the use of welded construction and stock purchased items, "We tried to make it as cheaply as possible. That is why we used so much welded construction. Also, rather than machine all the components in our shop, we used a lot of purchased items." (A list of the purchased items used, excluding small items such as nuts, bolts, screws., etc., is given in Exhibit B-5).

An assembly drawing of the finished machine is shown in Exhibit B-6. Exhibit B-7 shows the machine performing several operations. The machine was mounted on its own table, which consisted of a welded frame made from 1" x 1" iron angles and 3/16" thick steel plate.

In reviewing his design procedure on this job, Don emphasized the fact that he hardly strayed from the original design sketches. He commented, "The finished design is very much like the original concept." He further commented that about 75% of his time on the project was spent making the final detail and assembly drawings. Most of the remainder of his time was spent making very rough sketches on 8-1/2" x 11" paper. The final drawings were very similar to his rough sketches.

Machine Operation

Don explained how he expected the machine to be operated, "During rotary welding of the connectors a two jaw chuck, holding the can, was attached to the lower spindle. A drill chuck was temporarily mounted on the upper spindle with a locating plug which fit the connector mounts in the can. The plug was used to center the connector holes in the can on the lower chuch, After centering, the drill chuck was removed and the upper spindle was not needed. When welding the mating bellows flanges, however, both top and bottom spindles are used. Identical chucks were used on both spindles. The bottom chuck is to hold the large can, while the top chuck holds the small can. Both spindles are then rotated while the torch is held stationary.

During linear welding the spindles are not used. The parts to be welded are held stationary in a supporting fixture (Exhibit B-9) which fed an inert gas (usually nitrogen) into the can to back-up the weld, thereby improving the welded seam. The gas was fed in continuously and allowed to escape. A similar welding mandrel was used for welding the smaller can.

Cost of Fixture

George Dale, in charge of cost control for the microwave division, compiled the following cost figures for the heliarc welding fixture:

A. Initial Design Phase

	Labor Hours	Labor Dollars	Overhead Dollars	Material Dollars	TOTAL
Project Engineer	6	$ 42	$ 66		
Engr. Aide	25	95	150		
Design and Drafting	237	1036	1619		
Machinist (forming)	65	255	391		
Construction (assembly)	168	572	700		
Material and Hardware (including vendor machined parts)				$ 1435	
Labor Total		2000			
Overhead Total			2926		
Materials Total				1435	
TOTAL PHASE (A)					$6361

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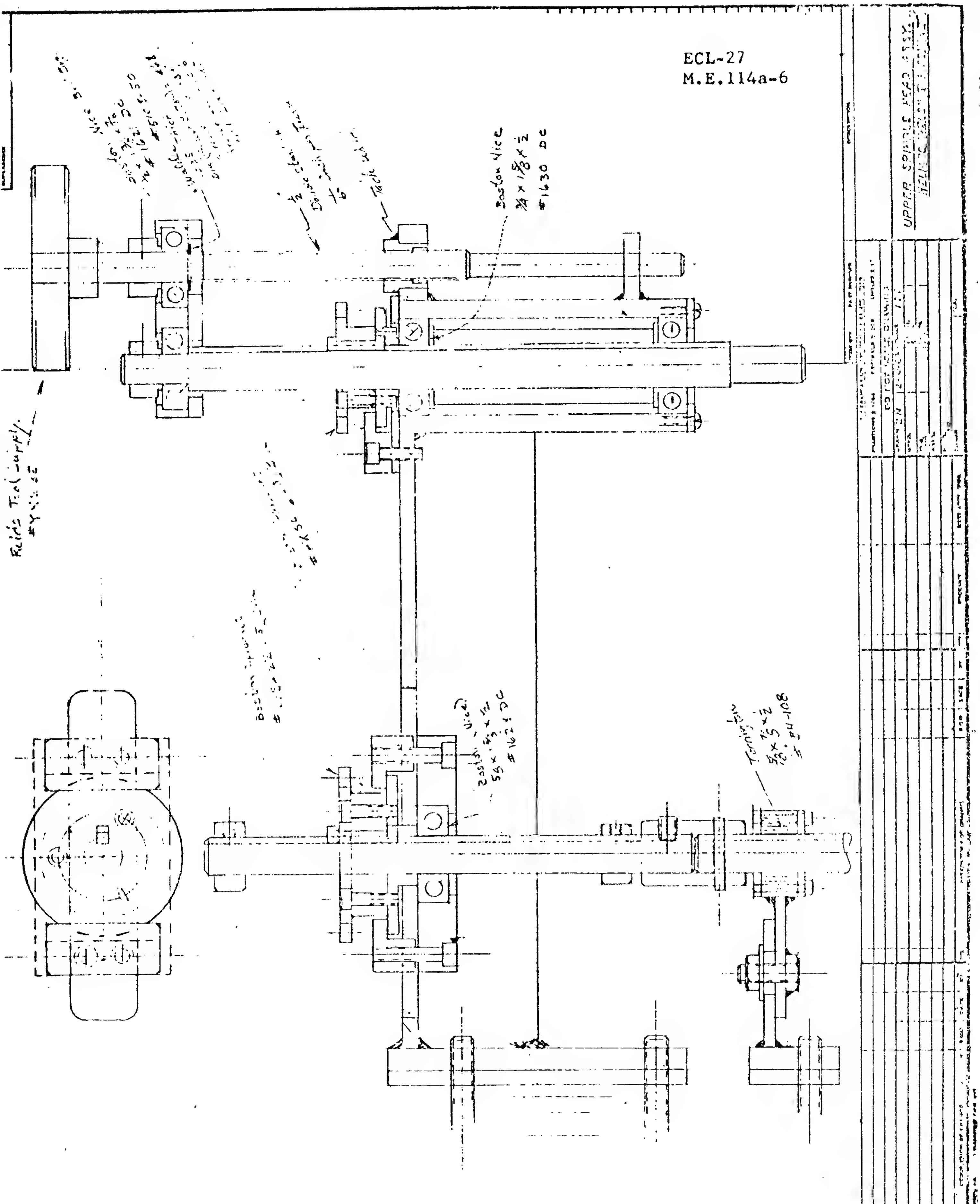

Exhibit B-1: Upper Spindle Assembly.

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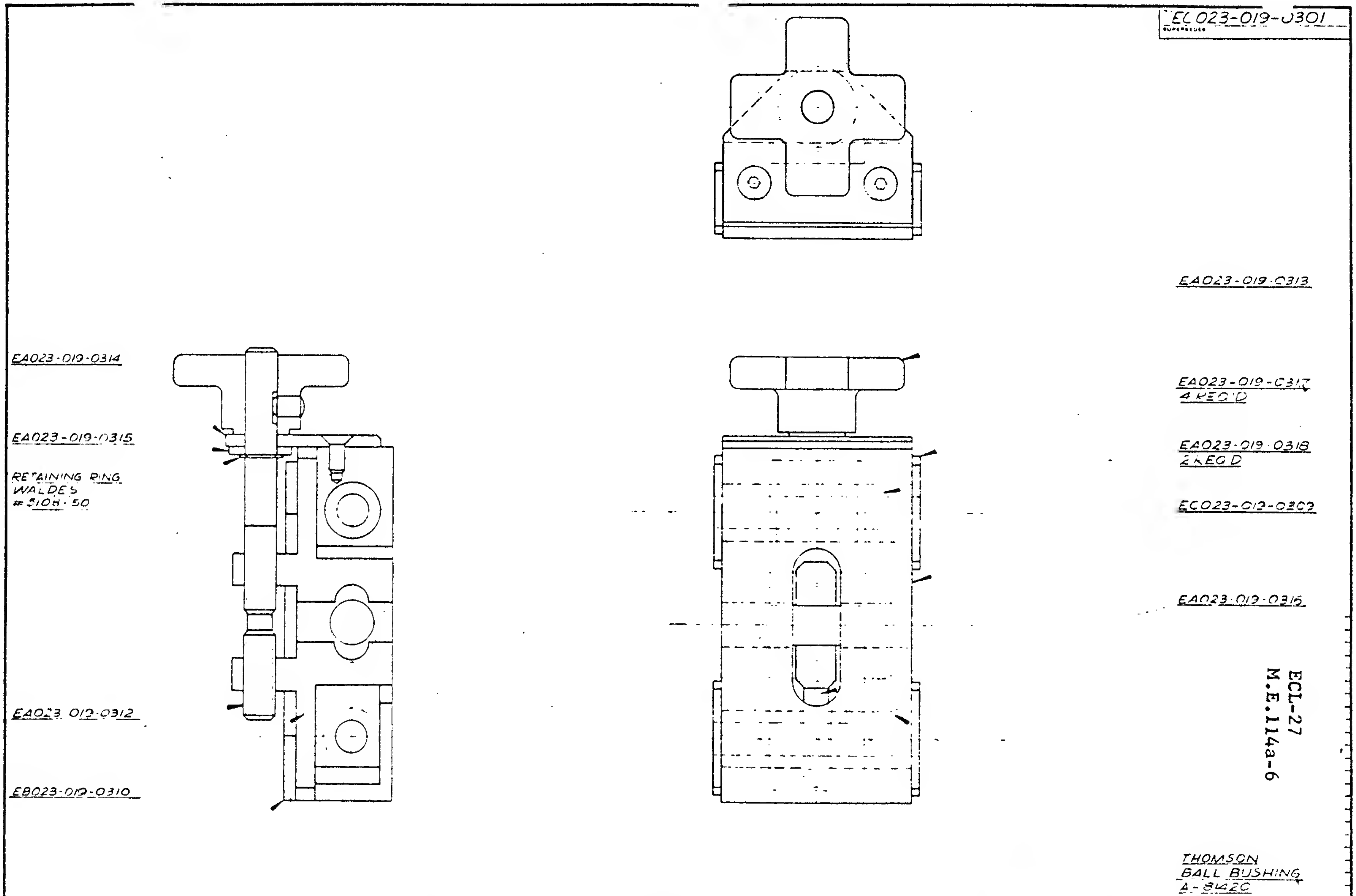

Exhibit B-2: Torch Carriage Assembly.

Exhibit B-3: Carriage Dri Assembly.

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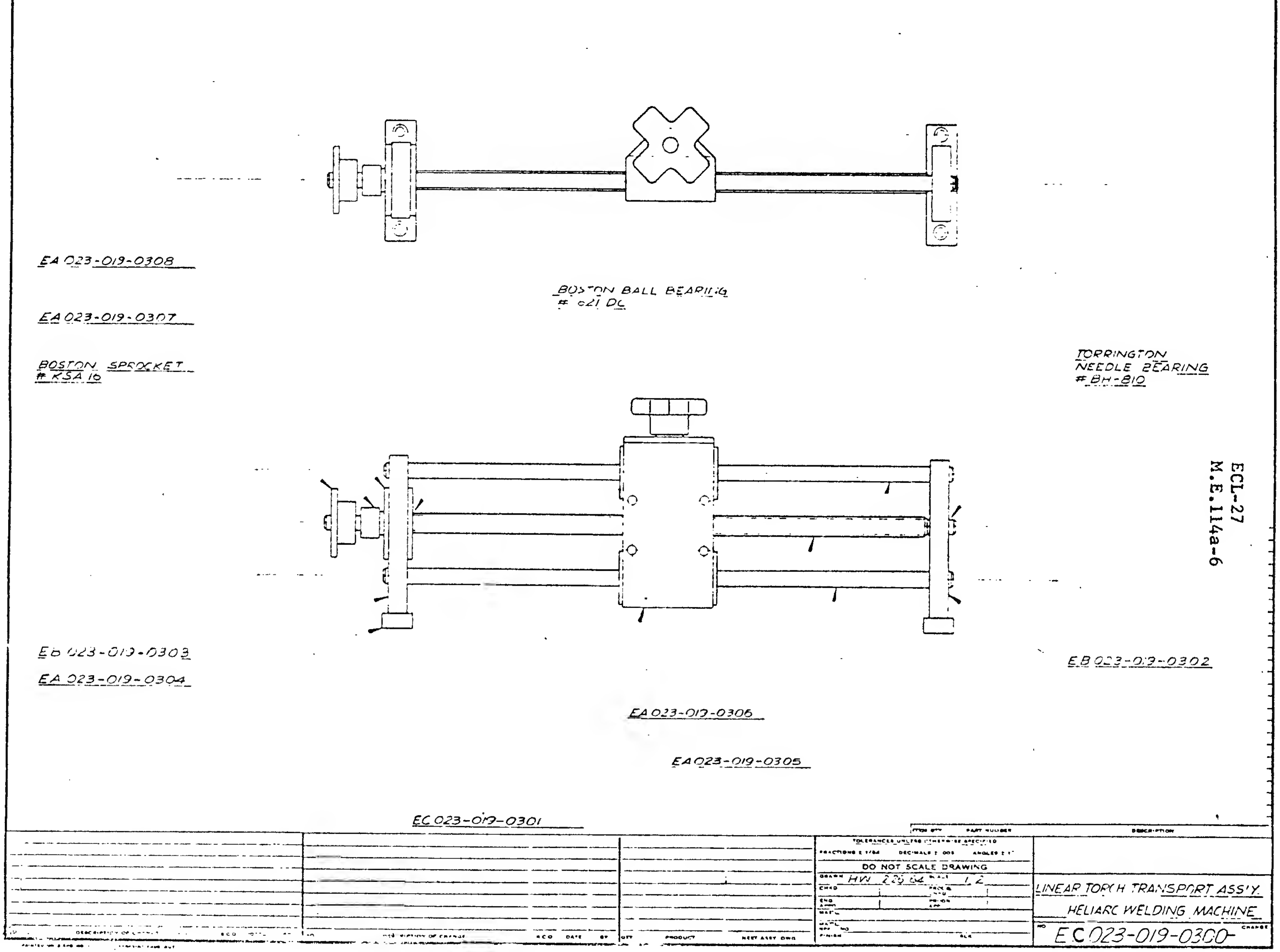

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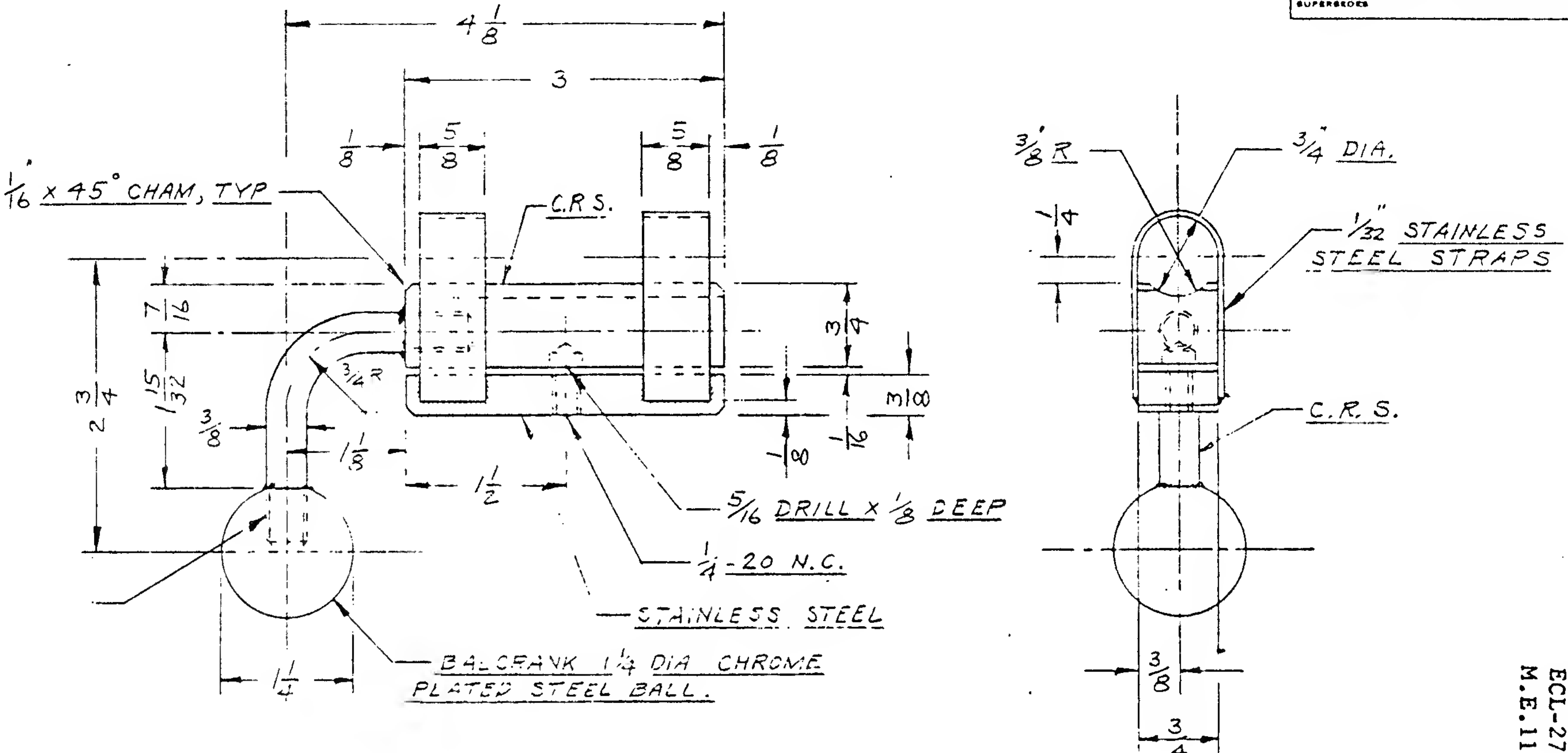


Exhibit B-4a: Torch Ball Clamp.

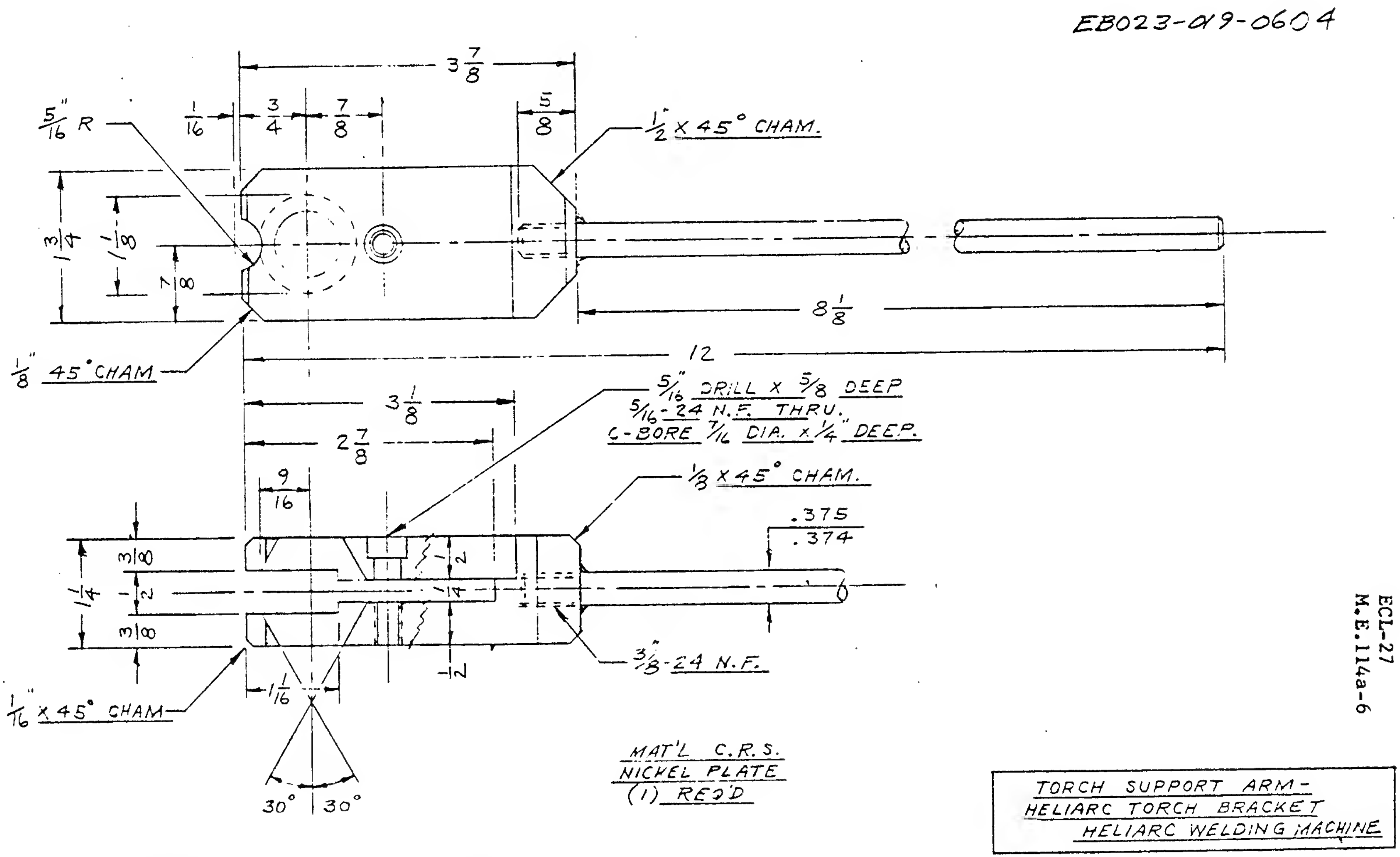


Exhibit B-4b: Torch Socket Clamp.

EXHIBIT B-5

PURCHASED PARTS LIST

(1) MOTOR, Bodine No. B2410-10H
Single worm reduction 10:1 ratio
Shunt wound, 1730 max. r.p.m.
Output r.p.m. 173 max.
1/15 h.p. , 115 v., D.C., self ventilated
Frame No. NSH-34RH, 5/8 output shaft

(1) SPEED CONTROL UNIT,

Millarick Speed Control
No. SH-52, 1/8 h.p. max.
Input: 115v, 60 cy.
Output for 115v, D.C., shunt wound motors
$75.00

(1) SOLENOID, National Acme Co.
Model K-100-C
Stroke 1", 4-7/16" long, 2-7/8" high, 2" wide
Approx. force = 11 lbs.

(1) WORM, Boston No. DH-1407 R.H.
12 Pitch, double thread
Soft steel, 14-1/2° P. angle
1" Pitch dia.

(1) WORM GEAR, Boston, No. D 1402
12 Pitch, 40 teeth, for double thread R.H. worm.
14-1/2° P. angle
3.333" Pitch dia., 1/2" face

(2) CAM FOLLOWERS,

Smith Bearing Division of Accurate Bushing Co.
No. CTA-1A
1/2" dia. x .344" roller
No. 10-32 n.f. x 1/2" lg. shank

(1) BOSTON SPROCKET,
No. HKSA16 with 3/4" bore

(2) BOSTON SPROCKET,
No. HKSA22 with 5/8" bore

(1) BOSTON SPROCKET,
No. HKSA16 with 5/8" bore

(1) BOSTON SPROCKET,
No. KSA-21 with 1/2" bore

(1) BOSTON SPROCKET,
No. KSA-16 with 1/2" bore

EXHIBIT B-5 (con't.)

(1) BOSTON No. 35 ROLLERLESS CHAIN,

8 ft. long
Boston No. 35 chain Separate Attachment Links
(3) roller links
(3) connecting links
(3) offset links

(1) BALL BEARING, (NICE)

Boston No. 1633

5/8 x 1-3/4 x 1/2 lg.

(2) BOSTON (NICE) BALL BEARING,

No. 1630 DC

3/4 x 1-5/8 x 1/2

(3) BOSTON (NICE) BALL BEARING,

No. 1628 DC

5/8 x 1-5/8 x 1/2

(3) BOSTON (NICE) BALL BEARING,

No. 1621 DC

1/2 x 1-3/8 x 7/16

(3) TORRINGTON ROLLER BEARING,
No. BH-810

1/2 x 3/4 x 5/8 lg.

(2) TORRINGTON ROLLER BEARING,
No. BH-1012

5/8 x 7/8 x 3/4 lg.

(1) TORRINGTON ROLLER BEARING
No. BH-108

5/8 x 7/8 x 1/2

(3) THOMSON BALL BUSHINGS

No. A-81420

1/2 bore, 7/8 O.D., 1-1/4" lg.

(2) THOMSON "60-CASE", Hardened and Ground (Class L)

Ball Bushing Rods x 19-1/4" lg.

(21-1/2" lg.) Ducummum threaded steel rod.

5/8"-11 N.C.

(4) WALDES KOHINOOR RETAINING RINGS

No. 5108-62 for 5/8 shaft

EXHIBIT 5 (con't.)

(2) WALDES KOHINOOR RETAINING RINGS,
No. 5108-50 for 1/2" shaft

(1) HANDWHEEL,
Reids Tool Supply No. YRS-35

(4) 1/2" SHAFT COLLARS, - BOSTON No SC 50

(2) 5/8" SHAFT COLLARS, - BOSTON SC 62

(1) 5/8" STEEL SLEEVE COUPLING, - BOSTON No. CR 10

(1) MONROE, CAST IRON KNOB HANDLE,
No. HKS-275, 2-3/4"o.d., 1/2" bore

(1) BOSTON FLEX SHAFT COUPLING,
No. FCR 15, one end 5/8"; other end 1/2"

(1) 3/16" DIA. ROLL PIN X 3/4" long
Elastic Stop Nut Corp - No. 59-040-187-0750

(1) BOSTON THRUST BEARING - No. 605
5/8" i.d. x 1-1/8" o.d. x 11/32" high

(2) BOSTON 3/8" SHAFT COLLARS
No. SC-37

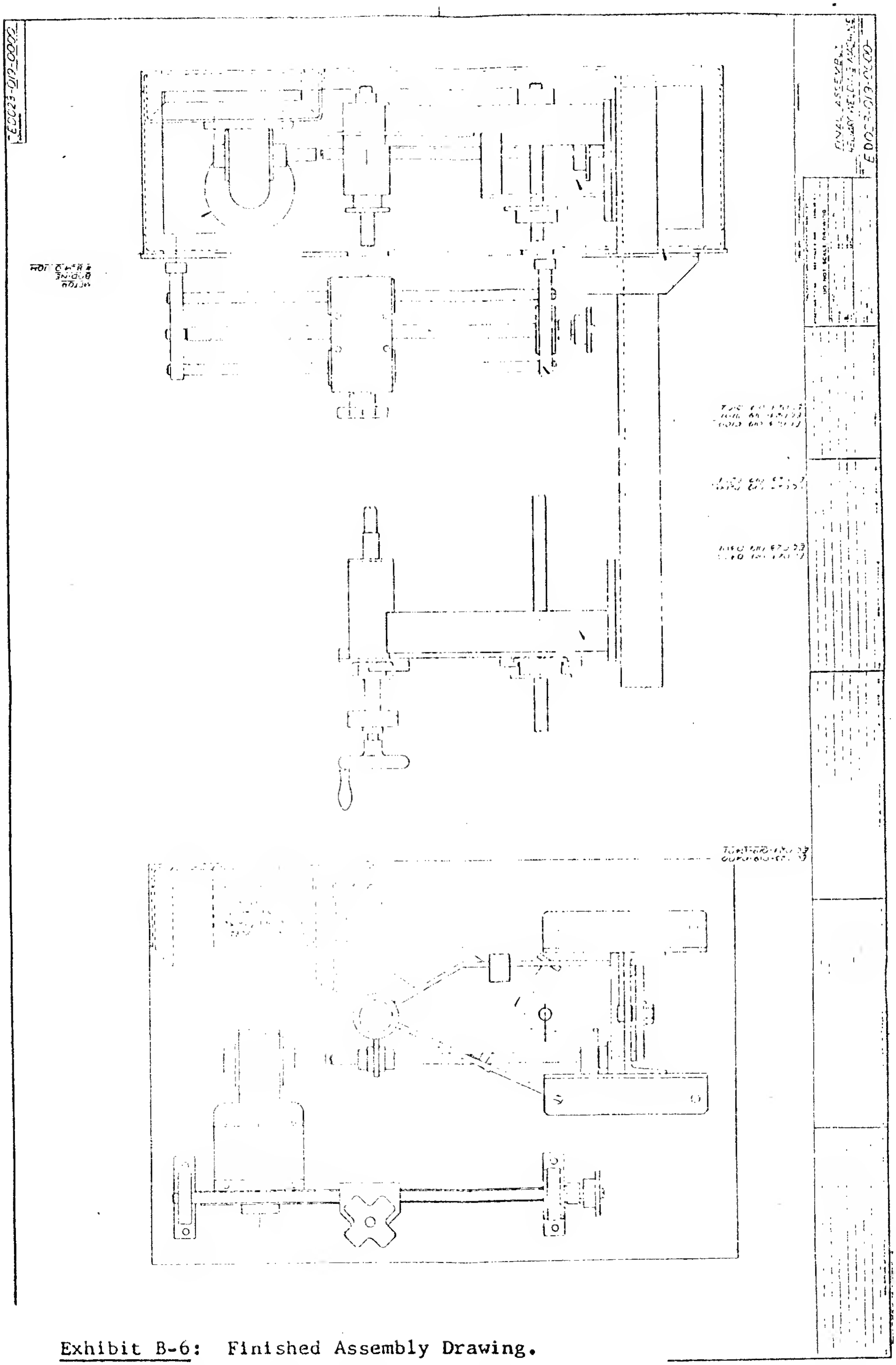
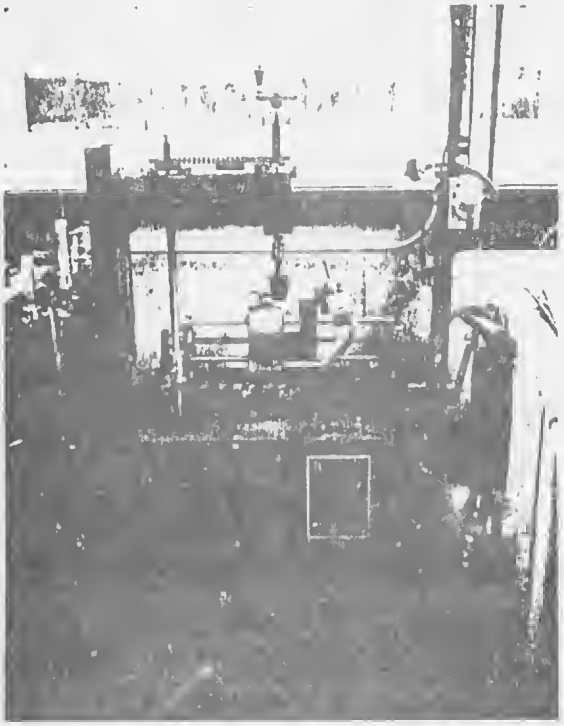
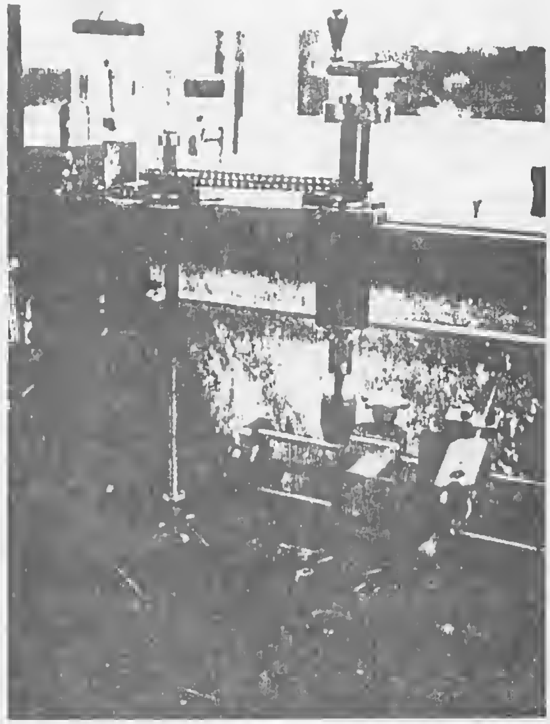
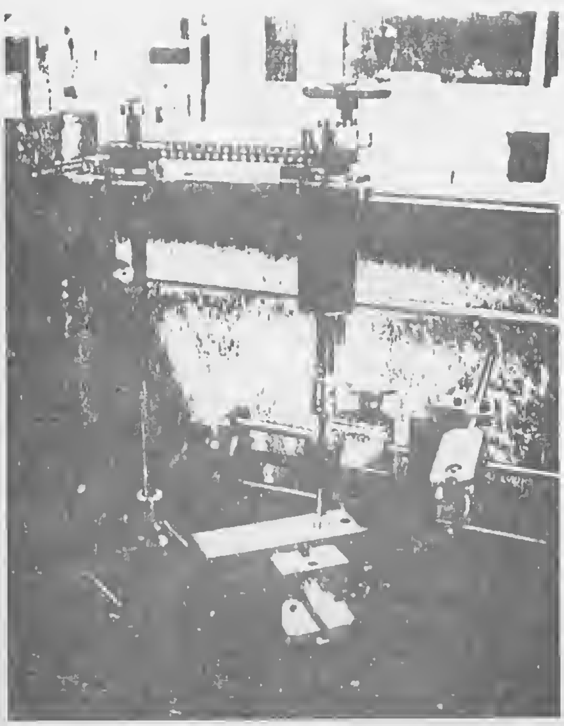
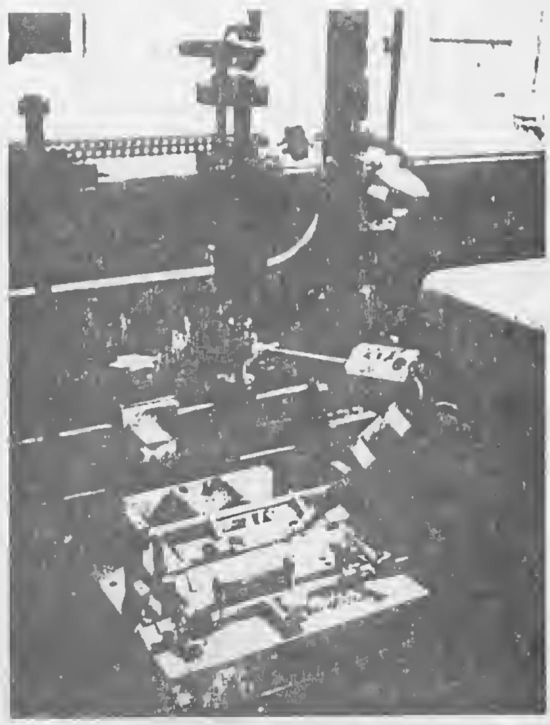


Exhibit B-6: Finished Assembly Drawing.





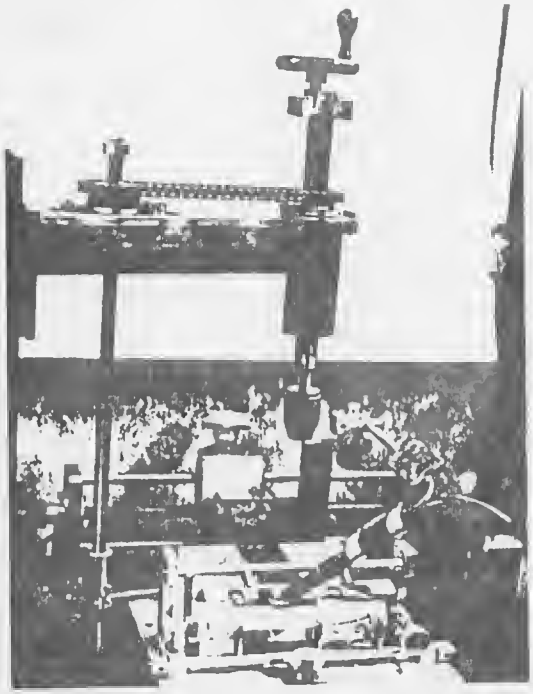


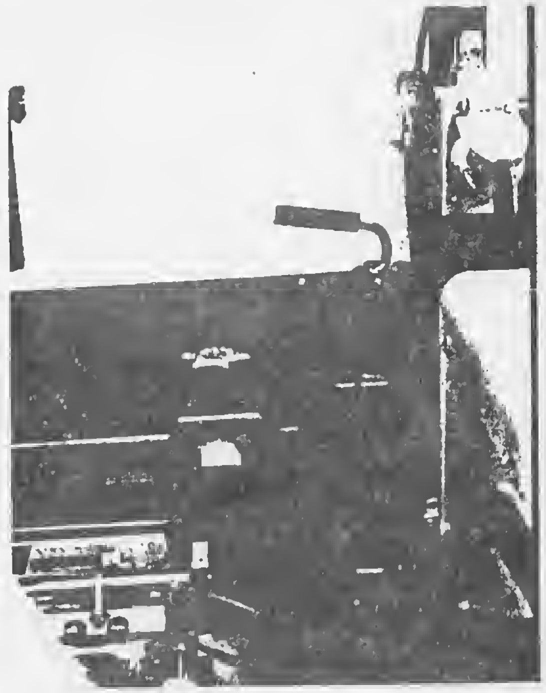


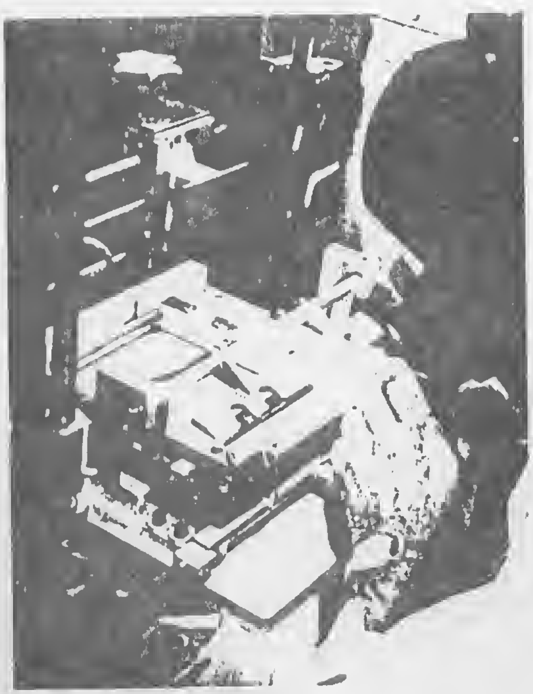
Chuck for Rotary Welding

Fixture for Linear Welding

Exhibit B-7:







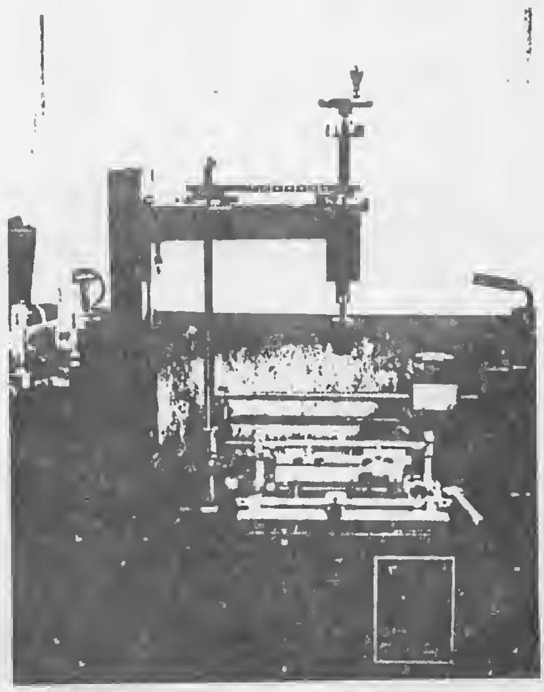


Exhibit B-7: (cont.)

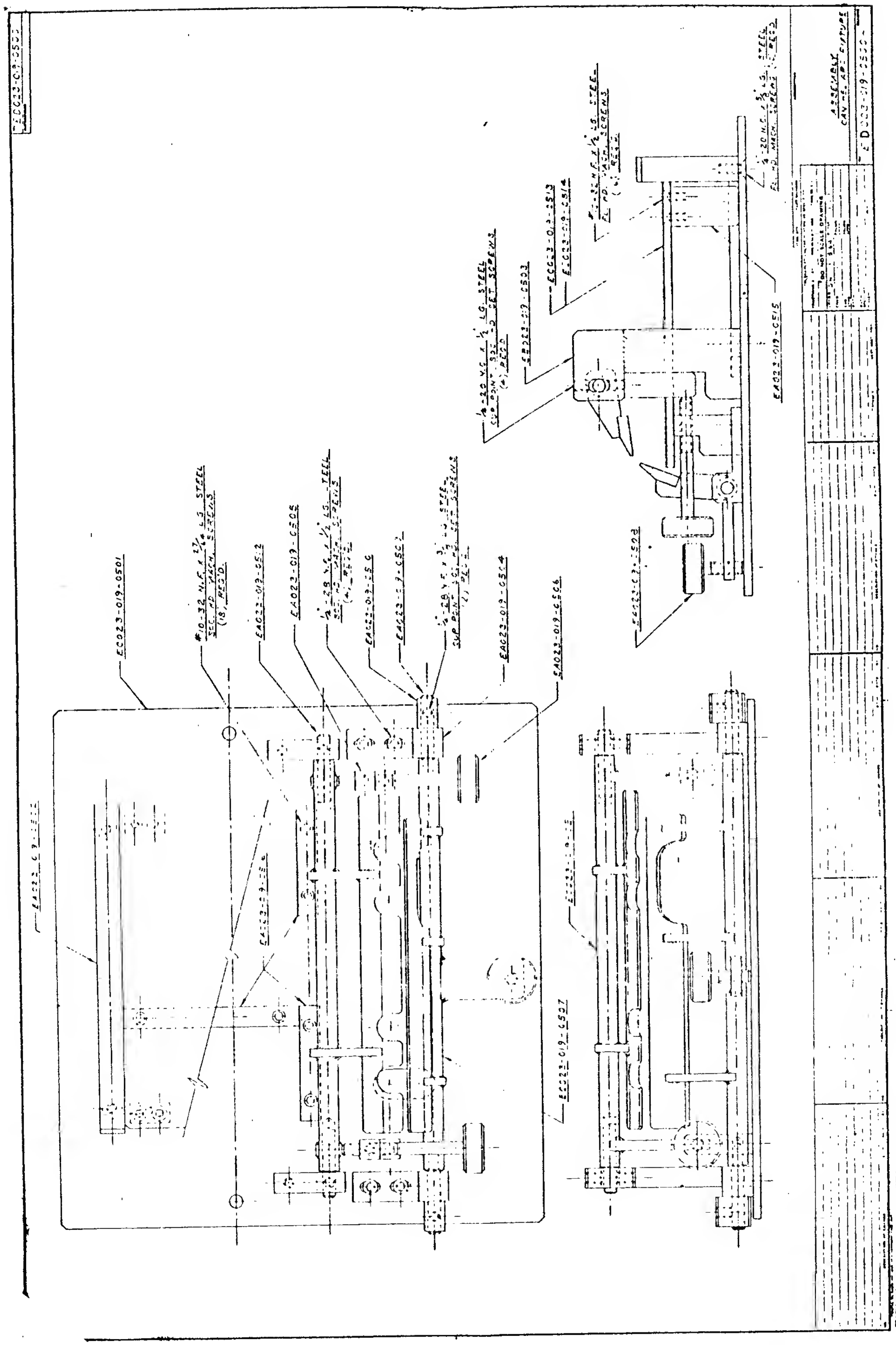


Exhibit B-8: Can Supporting Fixture for Linear Welds.

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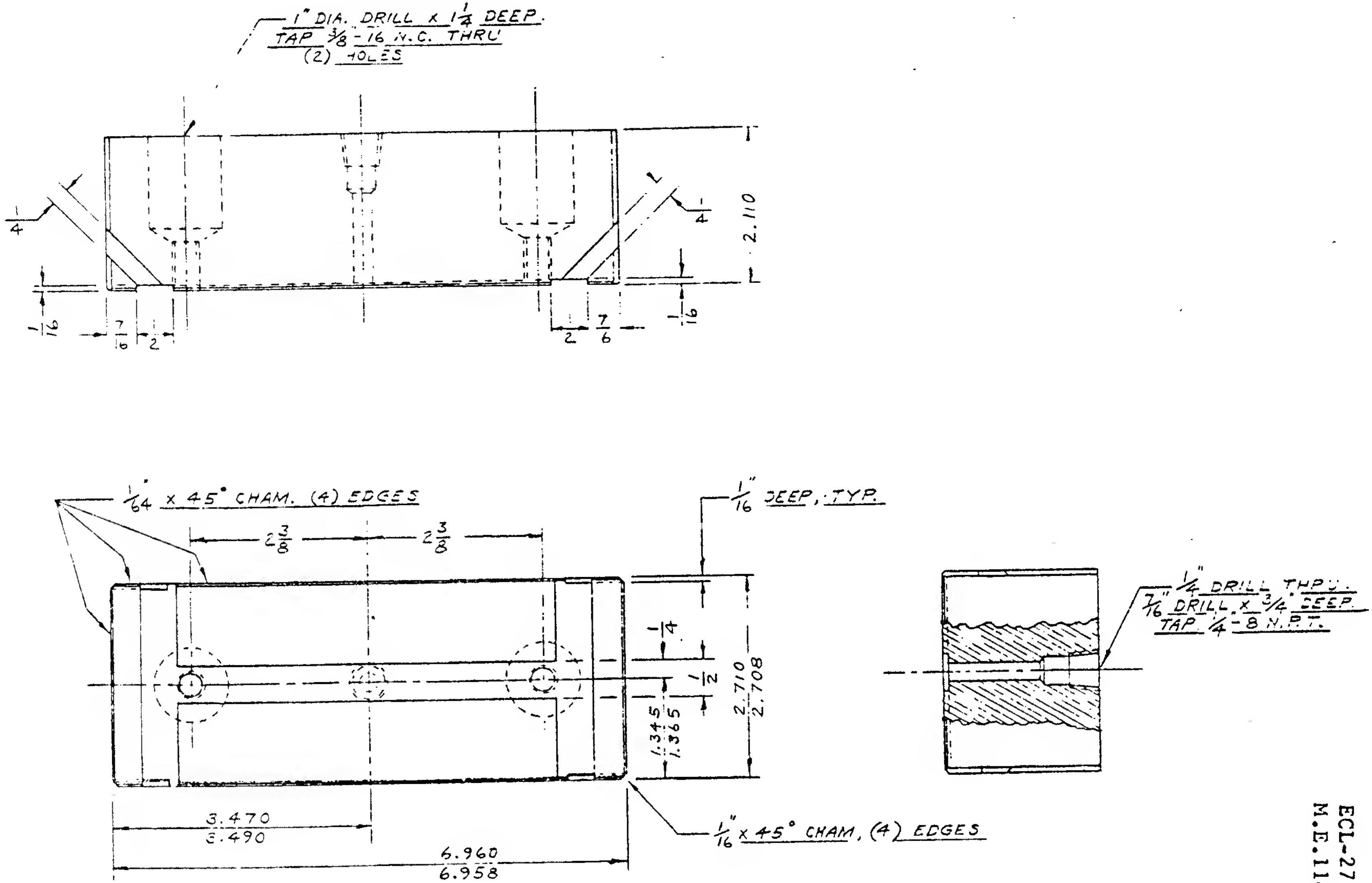
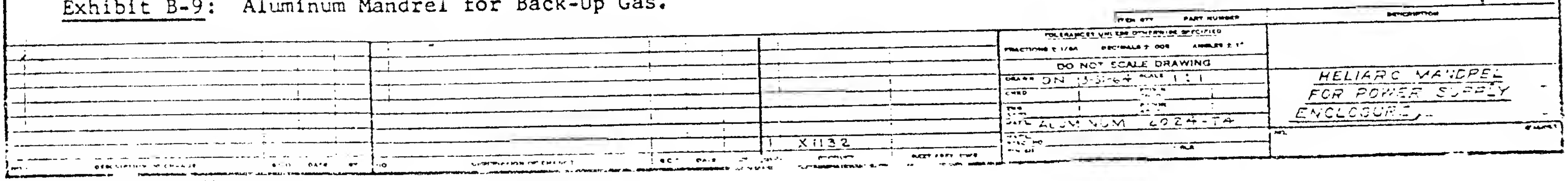


Exhibit B-9: Aluminum Mandrel for Back-Up Gas.



RADONICS, INC. (C)

Present State of the Heliarc Welding Fixture[1]

Just before Don issued the drawings for the machine to be made, he made the following observation, "I realized that by raising the entire linear traverse assembly, the fixture for holding the can during linear welds could be inserted underneath the carriage path, thereby reducing the reach from the torch carriage to the weld. I decided to go ahead and get the thing built, however, and, if necessary, make this modification later.

"After the machine was assembled, a welder tried several linear welds and found a serious fault which I had not foreseen. The cantilevered system consisting of the ball and socket joint, torch and cable had a natural frequency of vibration near the optimum operating speed of the gearmotor. The 1/2" diameter guide rods which supported the torch carriage were too small and consequently acted as a spring for the cantilevered torch system. As the motor speed was brought near the desired speed for welding, the torch began to vibrate excessively (approximately 1/16" up and down), causing an uneven weld. The welder found, however, that by turning the can holding fixture around and welding along the back edge the weld was satisfactory. This was, of course, because the torch arm was greatly shortened.

I had anticipated that the machine would have to go through a de-bugging stage where modifications would be made. Because of this, I did not have the machine plated and painted after the first assembly. During testing of the machine I made modifications to the original design. These included:

1. Raising blocks for the torch carriage traverse assembly.
2. Replacement of a soft washer on the worm shaft with a thrust bearing (I underestimated the thrust on the worm shaft. As a result, the soft washer taking the thrust soon showed wear.)
3. An idler sprocket for the traverse screw drive chain.
4. Chain guards (I planned for these all along, but never got to them until this stage in the design).

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[1] Based on a design problem discussed in RADONICS, INC. (A): Need for a Heliarc Welding Fixture, and (B): Design of a Heliarc Welding Fixture.

5. A tie bolt from the lower spindle mount to the underside of the table deck (to eliminate vibration in the lower spindle).

6. Removal of some material from the massive ball and socket joint.

All of the parts necessary for these modifications have either been made or purchased, but as yet non have been installed.

George Dale gave the following cost figures for this phase of the design:

B. Development of Shakedown Phase

	Labor Hours	Labor Dollars	Overhead Dollars	Material Dollars	TOTAL
Project Engineer	5	$ 35			
Engr. Aide	15	57			
Design and Drafting	55	241			
Machinist (forming)	15	58			
Construction (assembly)	83	283			
Labor Total		674			
Overhead Total			$ 950		
Materials Total				$ 160	
TOTAL PHASE (B)					$1784
TOTAL PHASE (A)					6361
GRAND TOTAL (to date)					$8145

Allotment of Tooling Costs

When Radonics undertook the project to produce the special electronic systems needed for a satellite transmission system, they were given a contract which allowed them to charge the sponsoring government agency with all expenses for specialized tooling related to the project. After inspecting the welding fixture and its cost figures, however, the government representative said that the government would not bear the cost of the fixture. The representative says the fixture can be used for other heliarc welding jobs and therefore is not a special item for use on this project. Engineers at Radonics discussed this matter several times with the government representative and explained that Radonics will probably never use the fixture again after this project is completed. For this reason, Radonics engineers feel the fixture should be regarded as a piece of specialized tooling, with its expense borne by the government.